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EFFECT OF NUTRITION ON CARCASS LEANNESS IN SWINE

by

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INTRODUCTION

The increasing consumer demand in recent years for pork cuts with more lean and less fat has stimulated interest in the production of meat-type market hogs. The heritability estimates for the various carcass traits have been summarized by Craft (1958). These estimates indicate that approximately 40-50 percent of the variation in the traits associated with carcass leanness is due to genetics. One could assume, therefore, that approximately 50 percent of the variation in these traits is due to environmental factors including nutrition. From this it appears that nutrition may exert somewhat less of an effect on carcass leanness than could be accomplished through proper breeding and selection. However, the type of ration fed has been shown to play an important role in affecting the ratio of lean to fat in the carcass.

In general, attempts to increase carcass leanness by alteration of the ration fed have resulted in a reduced growth rate. Two exceptions to this generalization are: 1) the feeding of higher levels of protein, and 2) the addition to the ration of certain additives.

In Europe greater emphasis has been placed upon the production of a quality carcass rather than on fast gains, and the restriction of feed intake by hand-feeding has been effective in the production of a leaner carcass (Clausen, 1960).

The purpose of this study was to investigate possibil-

ities of increasing carcass leanness through nutrition without sacrificing rate of gain or efficiency of production.

REVIEW OF LITERATURE

Effect of Protein Level on Carcass Leanness

A considerable volume of research has been reported concerning the effect of protein level on carcass leanness in swine. The majority of these reports indicate a positive relationship between level of protein in the ration, within limits, and percent lean in the carcass. In many of these studies the differences have probably been magnified somewhat by comparing a high protein ration with a ration too low in protein to support normal growth and body development.

In one of the early reports on the effect of nutrition on carcass leanness, Henry (1887) compared a ration consisting solely of a full feed of finely ground corn with a combination of dried blood, shorts and skim milk and observed an improvement in rate of gain, dressing percentage and muscling with the combination of ingredients which contained a higher percentage of crude protein. The straight corn diet resulted in a higher percentage of separable fat in the carcass. Later Henry (1890) starting with four month old pigs fed a combination of shorts and bran for 13 weeks followed by corn for six weeks and compared this with a corn meal diet fed throughout the entire growing-fattening period. The pigs receiving the shorts and bran during the period, which at that time would be referred to as the growing period, made much more rapid

gains on less feed per pound of gain and the carcasses contained a larger proportion of lean to fat than those fed corn throughout the entire feeding period. From these results Henry concluded that

> . . . the carcass of growing pigs is greatly affected by the character of the food given. If much corn is fed and nitrogenous foods withheld the pigs will become dwarfed and fatten prematurely with weakened bones, diminished blood and reduced vital organs. On the other hand, after the pigs have reached seven or eight months of age, there is far less necessity for nitrogenous foods and the cheapest gains can be made with corn. (p. 22)

Robison et al. (1952) in comparing rations containing 10, 12, 15, and 20 percent protein, reported regular increments in percent lean cuts as the dietary protein levels increased. There was a corresponding decrease in percent fat trimmings with increasing protein levels.

Woodman et al. (1936) reported a study in which a variety of protein sources were used in rations to study the influence of high levels of protein on the conformation of the bacon pig. Their low protein ration contained 17.5 percent protein, reduced to 16 percent at 90 pounds live weight, and further reduced to 12 percent at 150 pounds. The corresponding intermediate protein levels were 22, 20.5, and 17 percent, and the corresponding high protein levels were 27, 25, and 21.5 percent. The authors concluded that variations in protein levels from normal to abnormally high levels were without significant effect on backfat thickness. These workers were feeding very

high protein levels which may account for their failure to show a treatment response.

Starting with 40-pound pigs, Wallace et al. (1954) suggested that a corn-soybean oil meal ration well fortified with minerals and vitamins and containing 14.3 percent protein was as satisfactory for weight gains of pigs fed in dry-lot as rations containing 17.6 or 20.9 percent protein. These protein levels were lowered approximately three percentage units at 100 pounds live weight and the carcass grades revealed an advantage for the group of pigs receiving the high level of protein. Ashton et al. (1955) fed protein levels ranging from 10 to 20 percent and reported a significantly greater proportion of lean in the carcasses as the level of protein increased. The authors suggested that this increment in proportion of lean per interval of protein (two units percent) increase was of such small magnitude as to be of minor consideration in choosing between two adjacent protein levels; however, significant differences in backfat and percent lean cuts existed between the lower and higher protein levels.

In the work reported by Tribble and Pfander (1955) in which they fed two protein levels (16 and 12 percent) from weaning to 200 pounds, the carcasses from pigs fed the higher protein level contained 1.6 percent heavier lean cuts.

Recently Baur and Filer (1959) fed pigs from three days of age for eight weeks comparing a liquid infant food contain-

ing 3.45 percent protein with a commercial feed containing 25 percent protein. Chemical analyses of the carcasses from these young pigs revealed a marked increase in protein content of the carcasses from pigs fed the high protein ration with a corresponding decrease in the fat content of the carcasses.

Beacom (1959) conducted three trials in which he fed rations of low, medium, standard and high protein content. The approximate protein levels were 13, 15, 17, and 19 percent from weaning to 70 pounds; 12, 13.5, 14.5, and 15.5 percent from 70 pounds to 130 pounds; and 11, 12, 12.5 and 13 percent from 130 pounds to 200 pounds. He found no significant effect of protein level on carcass length or backfat thickness. However, as protein level increased there was a highly significant increase in loin eye size. Brooks and Thomas (1959) supplemented peanut oil meal rations with lysine and methionine and suggested that lysine might have a specific effect on loin eye area, but found no advantage in these amino acids in reducing backfat.

Morgan et al. (1959) demonstrated that pigs fed a standard (16.7 percent reduced to 13.5 percent at 150 pounds) level of protein showed superior performance in terms of growth and feed efficiency in comparison with a substandard (14.2 percent reduced to 11.8 percent at 150 pounds) protein ration. Appreciable differences in carcass quality including reduction

in backfat and total body fat, concomitant with an increase in the lean meat content, also resulted from variation in dietary protein levels.

Wallace et al. (1959) fed two levels of protein, 14 and 21 percent, from 60 to 195 pounds live weight and observed faster, more efficient gains on the lower protein ration; however, the higher protein ration resulted in a highly significant reduction in carcass backfat and dressing percentage.

By using different combinations of protein sources, Kropf et al. (1959) compared two 16 percent protein rations, one containing an apparently good amino acid balance and the other a poor amino acid balance, with a 12 percent protein ration containing an apparently good amino acid balance. Carcass data were obtained from pigs slaughtered at 85, 145 and 205 pounds live weight. There was little difference in rate of growth or feed efficiency between the high quality protein rations; however, growth rate was significantly reduced by feeding the ration poor in amino acid balance. In this experiment the higher protein ration resulted in greater muscle development and less fat deposition, and there was little difference in carcass leanness between pigs fed the 16 percent ration containing poor amino acid balance and those fed the low protein ration. Since the treatment differences in favor of the high protein good quality ration were greater at lighter body weights, the authors speculated that the other

two rations were more limiting in regard to essential amino acid content in the earlier stages of growth and thus retarded muscle development. The authors further suggested that at heavier body weights, these same rations may have been more than adequate.

Clausen (1960) reported data which indicated that lower than normal protein levels fed to lactating sows influenced the composition of the sow's milk and resulted in a higher percent fat in the carcasses of the pigs at slaughter when they were self-fed but made no difference if the pigs were limited-fed.

Effect of Energy Level on Carcass Leanness

One of the most common methods of increasing the proportion of lean to fat in swine carcasses has been to reduce the daily dietary caloric intake. This reduction has generally been accomplished by either limiting the total daily feed intake or by increasing the fiber content of the ration. Either of these methods has usually resulted in a slowing in growth rate.

Whatley et al. (1951, 1953) produced leaner pigs, as measured by less carcass backfat, higher carcass specific gravity, and higher percent lean cuts, by feeding a low energy ration. However, the carcass value per pound of live hog was reduced by feeding the low energy ration due to a lowered

dressing percent.

Merkle et al. (1953, 1958) fed a basal ration containing 76 percent TDN and compared it with rations containing 69 and 62 percent TDN made by dilution of this basal ration with corn cobs and alfalfa hay. The reduced TDN intake resulted in slower gains, decreased dressing percent and decreased backfat thickness.

The practicality of the use of high-fiber diets as a corrective measure against over-fatness in swine has been questioned by Coey and Robinson (1954). These workers fed rations varying from 3.5 to 11.5 percent crude fiber, but daily feed intake was controlled in such a manner as to equalize rate of gain between treatments. Even under these experimental conditions, as the fiber content of the ration increased dressing percentage and carcass backfat decreased.

Canadian workers have found it possible to improve bacon carcasses by "diluting" relatively highly digestible rations with fibrous feeds during the finishing period (Crampton et al., 1954b). In these investigations it was found that there was an increase in the percentage of Grade A carcasses with no reduction in rate of gain when the ration contained either 25 percent, by weight, wheat bran or 25 percent wild oats.

Kidwell and Hunter (1956) studied the feasibility of including high levels of alfalfa in growing-finishing swine rations and noted a marked reduction in rate of gain, dressing

percent and carcass backfat when the ration contained 50 percent alfalfa meal.

As a result of studies on the nutrient requirements for Canadian Yorkshire swine, Bell (1957, 1958) reported an improvement in the carcass grades when wheat was used to replace a portion of the barley in the ration even though this substitution resulted in an increase in the TDN of the ration. He also found that the use of oats as opposed to barley, as the grain in the finishing ration, resulted in an improvement of swine carcasses and he attributed this to the decreased daily energy intake.

More recently Hochstetler et al. (1959) studied the effect of varying levels of fiber of different sources upon growth and carcass characteristics of swine. These workers fed a series of rations containing 0, 20 and 40 percent oats; 0, 20 and 40 percent wheat bran; and 0, 10 and 20 percent alfalfa meal. There were no significant differences in feed lot performance or carcass characteristics between pigs fed rations containing 0, 20 and 40 percent oats. They reported a nonsignificant decrease in rate of gain and backfat as alfalfa meal was increased in the ration and there was a statistically significant decrease in rate of gain, feed efficiency, dressing percent and percent of fat trim in pigs fed a ration containing 40 percent wheat bran compared with the basal ration.

Another approach to limiting the daily caloric intake was reported by Ellis and Zeller (1931) in which they controlled the total daily feed intake by hand-feeding. In comparing full-feeding with 75 and 50 percent of full-feeding, the authors reported a reduction in daily gain and percent fat in the carcass as feed intake was reduced. Contrary to the studies where the energy intake was reduced by the addition of fibrous feeds, feed efficiency was improved by limited feeding. In a subsequent study, the same workers, Ellis and Zeller (1934), based their daily feed allowances on a percentage of the body weight, considering four percent of live weight as full-feed. They compared this with levels of three and two percent of live weight and in the case of corn basal diets found a significantly greater proportion of lean meat from pigs fed the restricted diets. However, no marked effect on body fat was noted when peanut meal basal rations were restricted to 50 percent of full-feed.

The work of McMeekan (1940) represented a unique approach in studying the effect on the carcass of limited feeding at different stages of body development. Twenty closely inbred pigs were made to conform to four major variations in the shape of the growth curve from birth to 200 pounds live weight. A high rate of growth throughout (High-High), a high followed by a low rate (High-Low), a low followed by a high rate (Low-High) and a low rate throughout the period (Low-Low) afforded comparison between animals of the same weight, but

different age, and between animals of the same weight and age but with differently shaped growth curves. The amount of skeleton and muscle increased and fat decreased in the following order of treatments: Low-High, High-High, High-Low and Low-Low. The author states that "the results obtained afford convincing evidence of the influence of the nutritional environment as a directive and controlling force in the development of the animal body." Winters et al. (1949) conducted a similar experiment except the different levels of feeding were not initiated until the pigs weighed 40 pounds and also no attempt was made to control the shape of the growth curve as was done in McMeekan's work. The group fed a restricted ration throughout the trial (Low-Low) required less feed per pound of gain and decidedly less nutrients per unit of gain when maintenance was taken into account. These animals produced the leanest carcasses. From this the authors concluded that less nutrients are required to produce a pound of lean meat than a pound of fat and assuming this conclusion to be valid, the authors further theorized that selection of breeding stock on the basis of economy of gains should be somewhat effective as a means of selecting animals that would yield a lean carcass.

Contrary to most reports, Brugman (1950) produced leaner pigs by limiting the feed intake from weaning to 150 pounds and then full-feeding to 220 pounds than by full-feeding the

pigs the entire period.

In studying the effects of breeding and nutrition on carcass leanness, Cummings and Winters (1951) found that in order for outbred hogs to make comparable yields of the five primal cuts to those of the best performing crossbred groups, it was necessary to restrict the feed intake for the outbred hogs to three percent of their body weight and prolong the feeding period. When restricted in this way they lacked the complete development of muscular tissue. Allowing for maintenance, it was found that less feed was required to produce a pound of lean than to produce a pound of fat.

Crampton et al. (1954a) divided into two groups pigs that had been fed all they would consume three times daily from 35 to 110 pounds live weight. One group was continued on this feeding program and the other group was limited to two pounds per day less than the full-fed group. A restriction of feed intake during the finishing period increased the quality of the hog carcass by reducing fat deposition. The percent lean was increased by the restriction of feed intake.

Lucas and Calder (1956) noted a sex-treatment interaction in studying the effect of plane of nutrition on carcass leanness. A restriction of feed intake after 100 pounds live weight reduced carcass backfat in gilts but was without effect in barrows.

In order to decrease daily feed consumption and thus to

limit the daily caloric intake of self-fed pigs, Jordan et al. (1956) added a mineral mixture to ground corn at levels ranging from three to 15 percent. Carcass leannes increased as the minerals fed increased above the six percent level. The authors stated that the increased minerals content of the feed did not result in a significant reduction in feed intake but may have reduced the digestibility of the feed consumed and in turn would have reduced the nutrients available to the pigs, causing the production of leaner pigs.

Effect of Antibiotics and Arsenicals on Carcass Leanness

The effect of antibiotics on carcass composition has been quite variable. Much of this variation can probably be, at least in part, attributed to the variable response to antibiotics in terms of gain and feed efficiency at different stages of the growth curve.

Catron et al. (1952) reported essentially no difference in carcass backfat when chlortetracycline was added to the ration for growing-finishing pigs. Wilson et al. (1953) increased percent lean cuts but failed to reduce backfat with the addition of either chlortetracycline or vitamin B_{12} or a combination of the two supplements. The effect on leanness was more pronounced on the low protein rations. Later Pierce (1954) reported no measurable effect of vitamin B_{12} or oxytetracycline on the chemical composition of carcasses from

hogs slaughtered at 200 pounds live weight. Similarly Kline et al. (1955) reported no appreciable influence by cobalt, vitamin B_{12} or a combination of four antibiotics on carcass leanness.

Huang and McCay (1953) found no significant effect on carcass backfat with the addition of oxytetracycline but did observe a decrease in percent lean cuts and an increase in dressing percent with the antibiotic supplementation. With the addition of chlortetracycline to the basal ration Kelley et al. (1957) reported a significant increase in carcass backfat in barrows but not in the case of gilts.

Perry et al. (1953) observed a significantly faster growth rate and significantly thicker shoulder backfat at the first rib with the addition of chlortetracycline to the ration. Chemical analysis of the carcasses revealed a significantly higher percentage of fat and a significantly lower percentage of water and protein with antibiotic supplementation.

Minnesota workers studied the effect of feeding three antibiotics, chlortetracycline, oxytetracycline and penicillin, separately, from weaning to 125 pounds as well as throughout the entire feeding period (Hanson et al., 1955). In the case of the tetracyclines, removal of the antibiotics at 125 pounds resulted in slightly less backfat than feeding antibiotics throughout the feeding period. This was not true in

the case of penicillin supplementation. In this experiment the trend toward fatter carcasses was associated with rate of gain, and the authors concluded that the antibiotics per se did not affect carcass quality. Stevenson et al. (1959) reported a significant reduction in backfat in pigs receiving chlortetracycline during the first half of the growing-finishing period compared to no antibiotic during this period.

In one trial reported by Lucas and Calder (1957) pigs fed penicillin had a significantly greater area of loin eye muscle. However, this observation was not confirmed in a second trial reported in the same paper.

Very little work has been reported concerning the effect of arsenicals on carcass conformation. Hudman and Peo (1958), working under conditions of a relatively low disease level, obtained no growth response with the addition of 3-nitro-4-hydroxyphenylarsonic acid to the ration but did show a slight improvement in carcass leanness as measured by the live backfat probe and by estimating the percentage of fat and lean by the method of Lu et al. (1958).

Brinegar et al. (1958) and more recently, Conrad et al. (1959) were unable to demonstrate any improvement in carcass leanness with arsenical supplementation to growing-finishing swine rations.

Effect of Hormones on Carcass Leanness

One area of research in which there is little disagreement between workers is the effect of difference in sex on carcass leanness. Whatley et al. (1953) observed that gilts produced leaner carcasses than barrows and the improvement in percent lean cuts of the gilts more than offset the higher dressing percent of the barrows in figuring the value of the carcasses. Zobrisky et al. (1959) found that boars had greater length of leg, width of shoulder, ham lean area, loin-eye area, yield of four lean cuts and size of bone than did littermate barrows, gilts or spayed gilts. The barrows were the most highly finished followed by the spayed gilts, gilts and boars.

Because of the leaner carcasses observed in the case of boars and gilts compared to castrates, much research has been reported concerning the effect of male and female sex hormones, and related compounds, on carcass conformation.

Woehling et al. (1951) failed to show a significant improvement in carcass leanness when either stilbestrol or testosterone was implanted in pigs. Carcass studies by Pearson et al. (1952) indicated that stilbestrol implantation did not materially affect dressing percent, thickness of backfat, carcass grade or tenderness. However, there was a trend toward reduced backfat with the implantation of stilbestrol.

Sleeth et al. (1953) reported no improvement in carcass

quality when either testosterone or estradiol was injected alone; however, the injection of a combination of these hormones resulted in a reduction in rate of gain and backfat.

An experiment reported by Bratzler et al. (1954) was designed to compare the effect of testosterone implantation of barrows with castration at various weights on carcass quality. Testosterone implanted barrows had less backfat than males that had been castrated at either 40 or 100 pounds. However, castration at either 140 or 180 pounds resulted in leaner carcasses than when testosterone was implanted. Boars slaughtered at 220 pounds were considerably leaner than those castrated at 180 pounds; however, the pork from these boars had a definite "off" flavor and odor. No objectionable odor or flavor was found in pork produced by animals castrated five weeks prior to slaughter.

Beeson et al. (1955) fed testosterone and stilbestrol to pigs and increased the percent lean cuts with testosterone administration. Stilbestrol-fed pigs were intermediate in fat content between control pigs and testosterone-fed pigs. Chemical analysis of carcasses showed that pigs receiving testosterone had about five percent less fat and five percent more lean than the controls. In four of five experiments reported by Johnston et al. (1957), methyl testosterone decreased rate of gain, daily feed consumption, feed efficiency and backfat thickness.

Heitman and Clegg (1957) observed slower gains and shorter carcasses with a greater percent of lean cuts when pigs were implanted with stilbestrol. Implantation with estradiol and progesterone gave results intermediate between the controls and those implanted with stilbestrol.

More recent studies at the Purdue Station by Thrasher et al. (1959) revealed no significant effect on live backfat depth with various combinations of feeding and implanting stilbestrol and testosterone.

Day et al. (1959) reported an improvement in percent lean cuts, area of loin eye and dressing percent and a decrease in live backfat probe when barrows were implanted with either stilbestrol or a combination of progesterone and estradiol benzoate.

In studies conducted by Hale et al. (1960) to investigate the effect of stilbestrol and testosterone in diets high and low in energy, testosterone decreased backfat of pigs on all diets; however, this effect was more pronounced in the pigs fed the low protein diets. Stilbestrol exerted no effect on backfat thickness. Neither hormone had an effect on carcass length or loin eye area.

Turman and Andrews (1955) presented convincing evidence of the positive effect of growth hormone on carcass leanness in swine. The carcasses from pigs receiving daily injections of growth hormone contained significantly more protein and

moisture and less fat than did the carcasses of control pigs.

From the results at the Purdue Station on the effect of thyroprotein and thiouracil on carcass quality (Beeson et al., 1947; Perry et al., 1948, 1950) it appeared that these compounds had very little, if any, positive effect on carcass leanness.

Effect of Fish Oils on Carcass Leanness

Many studies have been conducted to determine the effect of fish oils on the quality of fat produced in swine. However, very few reports have appeared in the literature concerning the effect of these oils on the quantity of fat produced in swine.

A lowering of the fat percentage in the milk of dairy cows has been demonstrated experimentally with the feeding of cod liver oil (Maynard and Loosli, 1956). These authors suggested that the specific unidentified factor in the oil responsible for lowering the fat percentage is found in the saponifiable fraction and that this property is not shared by fish oils generally. Worden (1958) reported an improvement in feed efficiency with the addition of cod liver oil to swine rations and when the oil was added at two and five percent of the ration, there was a slight reduction in carcass backfat.

Anglemier and Oldfield (1957) fed four levels of pilchard (California sardine) oil to pigs and reported a reduction in

carcass backfat as the level of oil increased.

Oldfield and Anglemier (1957) found no effect on thickness of backfat with the addition of five percent crude or modified menhaden oils to swine rations.

INVESTIGATIONS

The series of experiments which comprise this study is on file in the Animal Husbandry Section of the Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa. The ten experiments reported herein are under the title of Swine Nutrition Experiments 811, 877, 888, 941, 962, 975, 987, 1033, 1050 and 1051. The research was divided into three areas to study the effect of nutrition on carcass leanness in swine. The first area was concerned with an arsenical 3-nitro-4-hydroxyphenylarsonic acid (hereafter abbreviated as 3-N-4-HPAA) and two different dietary protein levels. The second area pertained to cod liver oil and the third phase was a study of a muscle relaxant, styramate.

Certain management and experimental practices were common to all experiments and these will be discussed at this point to avoid unnecessary repetition in the discussion of each individual experiment.

All pigs were obtained from the swine nutrition farm breeding herd. In general, the animals were crossbred with the breeding of Farmer's Hybrid, Landrace and Yorkshire predominating. Within 24 hours after birth, each pig was weighed and ear notched. The eye teeth were clipped and the pig was given an iron treatment for the prevention of anemia. All male pigs, except those used in Experiment 1050, were castrated at approximately five days of age. At four to five

days of age all pigs received an injection of approximately one cubic centimeter of a cholera-erysipelas antiserum mixture per pound of body weight. This mixture was made up of two parts cholera antiserum and one part erysipelas antiserum. At six to eight weeks of age, the pigs received injections of modified hog cholera virus and antiserum and erysipelas bacterin.

The pigs were weaned between 12 and 18 days of age and, except for experiments 811, 975 and 1050, were used in other baby pig nutrition studies for a period of four to six weeks prior to being selected for these studies.

Pigs weighing from 30 to 50 pounds were selected for most of these experiments. Piperazine phosphate, mixed in the feed for one day, was used to treat for internal parasites and either benzene-hexachloride or a similar preparation was used to treat for external parasites prior to the start of the experimental period.

Except for Experiment 1050, the pigs had free access to feed and water which were provided by self feeders and automatic float controlled water fountains.

Animals that died during the experiments, or were removed from the experiments because of illness, were taken to the Iowa State University Veterinary Diagnostic Laboratory for examination. Diagnoses for the pigs that were removed

during the experiments are presented in Table 33.[1] The gain for the remaining pigs in the pen was used in calculating average daily gain for that pen. The feed per pound of gain was adjusted by subtracting the calculated feed consumed from the total feed consumed to date. In this adjustment the assumption was made that the feed efficiency for the pig removed was the same as for the other pigs in the pen. If the pig removed had not gained weight between the time of removal and the preceding weigh day, no feed was charged to that pig for that period.

In all experiments, except Experiments 975 and 1050, the pen was considered the experimental unit and the data were analyzed on that basis, according to the methods described by Snedecor (1956) and Cochran and Cox (1957). Statements concerning statistical significance, or significance, pertain to the probability level of five percent or less.

In the experiments in which carcass data were collected, the pigs were weighed, without shrink, as they approached 200 pounds body weight. Since pigs were slaughtered on only one day of any week, any pig weighing 194 pounds or more on the day the pigs were sent to the packing plant was removed from the experiment that day. Therefore, the average final weight in most experiments was very close to 200 pounds. After the

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[1]The tables referred to in this thesis are found in the Appendix.

pigs were weighed a live probe (Hazel and Kline, 1952) was taken. Probe measurements were taken behind the shoulder and over the back and loin corresponding to anatomical sites over the sixth rib, over the last rib and over the last lumbar vertebra. All probe sites were 1.5 to 2 inches to the right of the midline of the body. The measurement used was the average of the three probes adjusted to a 200 pound live weight basis using correction factors suggested by Durham and Zeller (1955).

After the pigs were probed, they were tattooed and sent to the packing plant of Geo. A. Hormel and Co., Fort Dodge, Iowa where they were slaughtered the following morning. The head and leaf fat were removed at the time of slaughter. The carcasses hung in the cooler (approximately 36 degrees Fahrenheit) for 24 hours and then a chilled carcass weight was recorded just prior to cutting.

Carcass backfat was the average of three measurements taken at the first rib, last rib and last lumbar vertebra, measured to the nearest five-hundredths of an inch. This measurement was corrected to a 200 pound live weight basis by the same method as was used for the live probe adjustment. The carcass length was measured from the forward point of the aitch bone to the forward point of the first rib to the nearest five-hundredths of an inch.

In Experiments 987, 1033 and 1051, tracings of the loin

eye (cross section of longissimus dorsi muscle) were taken at the tenth rib at the time of cutting and were later measured with a planimeter, giving the area to the nearest one-hundredth of a square inch. The sample regression of loin eye area on the chilled carcass weight was calculated for each of these experiments and the areas were adjusted accordingly for differences in weight.

The percent of lean cuts was determined by dividing the sum of the weights of the trimmed hams, trimmed loins, trimmed picnics and Boston butts by the chilled carcass weight and multiplying by one hundred. All cuts were weighed to the nearest one-tenth pound. The dressing percent was determined by dividing the chilled carcass weight by the live weight and multiplying by one hundred.

Arsenical Studies

Experiment 811 - Levels of 3-N-4-HPAA for growing-finishing pigs

Objectives The purpose of this experiment was to compare the effects of four levels of the arsenical, 3-N-4-HPAA, on gains, feed efficiency and backfat, as measured by the live probe, on growing-finishing pigs.

Procedure Forty-six crossbred pigs were weaned at two weeks of age and all were placed on a 20 percent protein, pre-experimental ration containing 20 percent dried skimmilk.

These pigs were housed in the Beech Avenue Unit which is normally used as a baby pig nursery. The temperature in this building was thermostatically controlled during the winter months at 45 to 55 degrees Fahrenheit. In summer the temperature fluctuated with environmental temperature; however, an evaporative-type air conditioner was used during the early part of the experimental period to decrease the temperature inside the unit. The experimental period was from September to January.

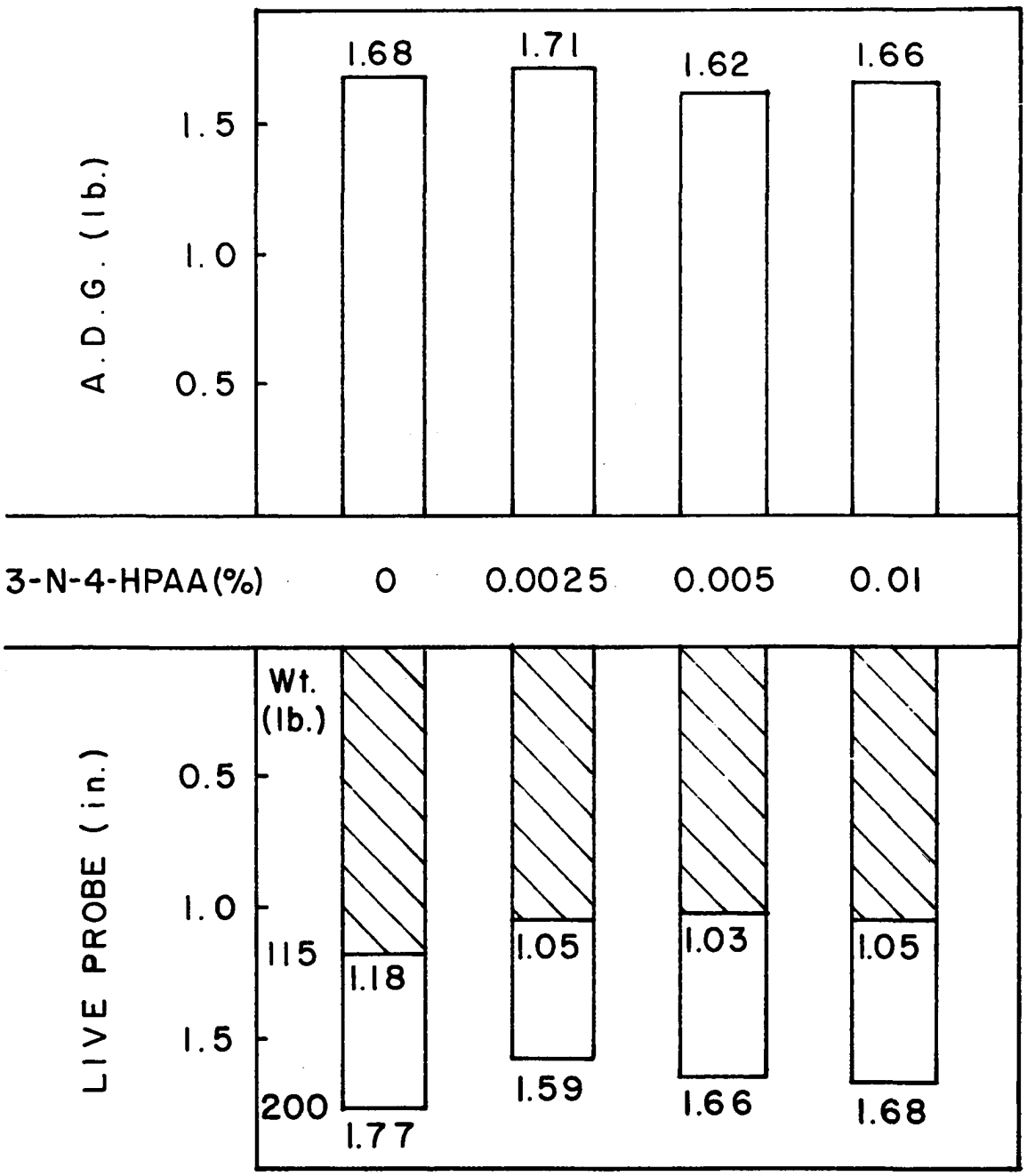
After one month on the preliminary diet, in which there were four to five pigs per pen, eight uniform littermate outcome groups of four pigs each were selected from the group of 46 pigs and randomly allotted from within outcome groups to the four ration treatments containing 0, 0.0025, 0.005 or 0.01 percent 3-N-4-HPAA. The restriction was placed on the allotment that four barrows and four gilts would be assigned to each ration treatment. In the allotment of these pigs no two littermate pigs received the same ration treatment unless eight pigs were used from the litter so that two pigs from the litter would be assigned to each arsenical level. This experiment involved eight replicated pens of one pig per pen for each ration treatment. The initial weight and age of the pigs were 30.3 pounds and 47 days, respectively. The composition and the calculated analyses of the basal rations are shown in Tables 1 and 4, respectively.

The pigs were weighed at weekly intervals and the feed consumed during that period was determined. Live probes were taken when the group averaged 115 pounds body weight. These probes were adjusted to a constant weight of 115 pounds by dividing the weight of the pig into 115 and multiplying this result by the live probe measurement. The pigs were again probed for backfat when they weighed 200 pounds ± five pounds. This probe was adjusted to a 200 pound live weight basis.

Results and discussion The individual pig data are presented in Tables 11 and 12 and are summarized in Figure 1. The analysis of variance plan and the statistical analyses for the live probes are found in Table 13.

There were essentially no differences between arsenical levels with respect to rate of gain or feed required per pound of gain. The failure of 3-N-4-HPAA to elicit a growth response can possibly be attributed to the apparently low disease level in this experimental unit. The rate of gain for the pigs during the experimental period could be considered above average. The addition of the arsenical appeared to result in a reduction in depth of backfat particularly at 115 pounds body weight. When the probe data for the three added levels were pooled and compared to the basal ration, this difference was statistically significant. There was no significant difference in backfat probe at 200 pounds due to ration treatment. However, when 3-N-4-HPAA was added at 0.0025 percent of

Figure 1. Experiment 811 - Effects of levels of 3-nitro-4-hydroxyphenylarsonic acid on average daily gain and live probe taken at 115 and 200 pounds body weight


A.D.G. (lb.)
1.5
1.0
0.5
1.68
1.71
1.62
1.66
3-N-4-HPAA(%)
0
0.0025
0.005
0.01
LIVE PROBE (in.)
Wt. (lb.)
0.5
1.0
1.5
115
200
1.18
1.77
1.05
1.59
1.03
1.66
1.05
1.68

the ration, a ten percent reduction in the live probe measurement was observed. The simple correlation coefficient between the live probes at 115 and 200 pounds was 0.80.

Experiment 877 - Effect of 3-N-4-HPAA on carcass leanness in swine

Objectives The results of Experiment 811 indicated that 3-N-4-HPAA might be effective in reducing backfat in swine. It was the purpose of this experiment to explore this possibility with a larger number of pigs fed in an environment similar to that which could be expected under typical farm conditions.

Procedure Ninety-six crossbred pigs averaging 26 pounds body weight and 48 days of age were randomly allotted across four treatments from littermate outcome groups. The treatments, copper sulfate (0 and 0.1%) and 3-N-4-HPAA (0 and 0.0025%), were arranged in a 2 x 2 factorial. Each treatment was replicated three times with eight pigs per pen. The composition and the calculated analyses of the basal rations are presented in Tables 1 and 4, respectively.

The experiment was conducted during the months of April through July in dirt-dry-lots. These lots were 78 feet long by 16 feet wide with a concrete slab at one end of the lot where the self feeders and automatic waterers were located. Each pen had an individual hog house with a wooden floor.

After 42 days on experiment two pigs were removed from

each pen due to inadequate shade facilities. When the pigs averaged approximately 125 pounds, the protein level was lowered from 16 to 12 percent.

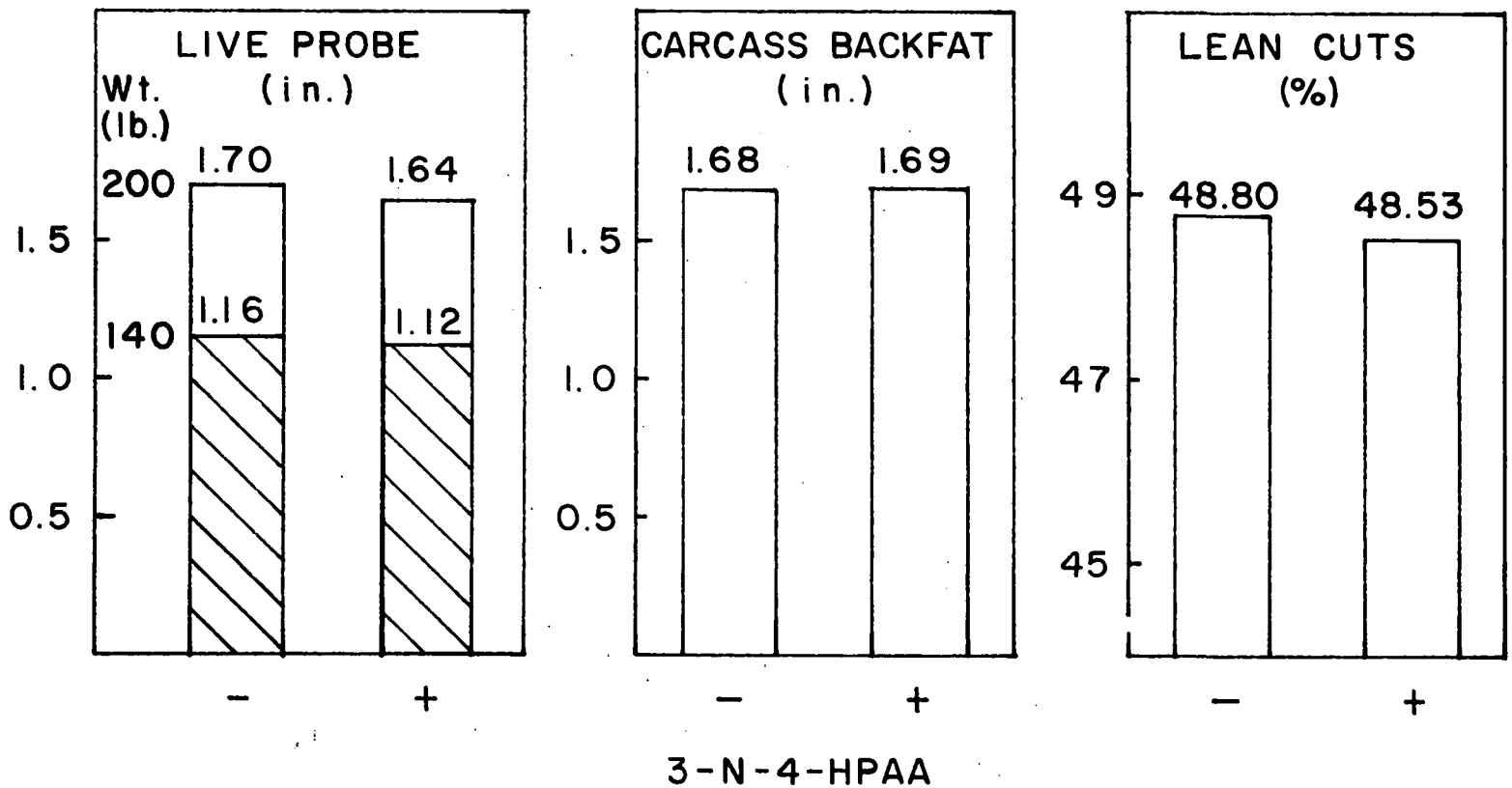
Live probes were taken when the pigs averaged 140 pounds and again when they were removed from the experiment to be slaughtered, at which time carcass data were collected.

Results and discussion The summaries of gain, feed efficiency and carcass measurements are presented in Table 14. The carcass measurements are also summarized graphically in Figure 2. The analysis of variance plan for the live probe at 200 pounds body weight and for lean cuts is found in Table 15.

A discussion on the effect of copper sulfate in this experiment has been presented previously (Hawbaker, 1959).

The addition of 3-N-4-HPAA to the basal ration resulted in practically no increase in rate of gain but did improve feed efficiency slightly. The live probes indicated a slight advantage in carcass leanness when 3-N-4-HPAA was fed. However, the carcass backfat, measured at the packing plant, and the percent lean cuts failed to support this observation. There were no significant differences due to ration treatment in any of the carcass measurements.

Figure 2. Experiment 877 - Effects of 3-nitro-4-hydroxyphenyl-arsonic acid on live probe taken at 140 and 200 pounds body weight, carcass backfat and percent lean cuts


LIVE PROBE
Wt. (lb.)
(in.)
200
140
1.70
1.64
1.16
1.12
1.5
1.0
0.5
CARCASS BACKFAT
(in.)
1.68
1.69
LEAN CUTS
(%)
49
47
45
48.80
48.53
-
+
3-N-4-HPAA

Experiment 888 - Effect of 3-N-4-HPAA and protein level on carcass leanness

Objectives The results obtained in Experiment 877 failed to lend support to the initial observation, based on the live probe data in Experiment 811, that 3-N-4-HPAA might be effective in reducing the backfat in pigs. As was pointed out earlier the reduction in live probe with the addition of 3-N-4-HPAA in Experiment 811 was more pronounced at 115 pounds body weight than at 200 pounds. It should also be noted that the protein levels fed were somewhat higher in Experiment 811 than Experiment 877, especially during the early part of the experiment. It was thought that if 3-N-4-HPAA did exert a real effect on carcass composition, this response might be mediated through some alteration in protein metabolism in the pig. With this in mind, Experiment 888 was designed to investigate the effect of the following on carcass conformation: 1) 3-N-4-HPAA, 2) protein level and 3) the possibility of a 3-N-4-HPAA x protein interaction.

Procedure The composition and the calculated analyses of the basal rations are presented in Tables 2 and 5, respectively. The initial protein levels chosen for this experiment were 20 percent protein for the "high" protein ration and 14 percent protein for the "low" protein ration. The protein level of the rations was lowered two percentage units when the pigs weighed approximately 50 pounds and again at 125

pounds. Changes in percent protein in the rations were accomplished by a change in the ratio of corn to soybean oil meal. Therefore, the rations differing in protein level were not isocaloric. The arsenical was added at the level of 0.0025 percent of the ration.

Eighty crossbred pigs were randomly allotted from littermate outcome groups to the four ration treatments, low protein basal, low protein basal plus 3-N-4-HPAA, high protein basal and high protein basal plus 3-N-4-HPAA. This experiment consisted of five replicated pens of four pigs each per ration treatment. The average initial age of the pigs was 48 days and the average initial weight was 31 pounds. The experiment was conducted on concrete during the months of May through August.

Live probes were taken when the pigs averaged 130 pounds and again at 200 pounds at which time the pigs were slaughtered and carcass data were obtained.

Results and discussion Summaries of average daily gain, feed required per pound of gain and carcass measurements are presented in Table 16. The analysis of variance plan and observed mean squares are found in Table 17. The treatment means for average daily gain and carcass measurements are illustrated in graphic form in Figures 3 and 4.

From the work of Catron et al. (1952) one would expect little difference in rate of gain between the protein levels

Figure 3. Experiment 888 - Effects of 3-nitro-4-hydroxy-phenylarsonic acid and protein level on average daily gain and live probe taken at 130 and 200 pounds body weight

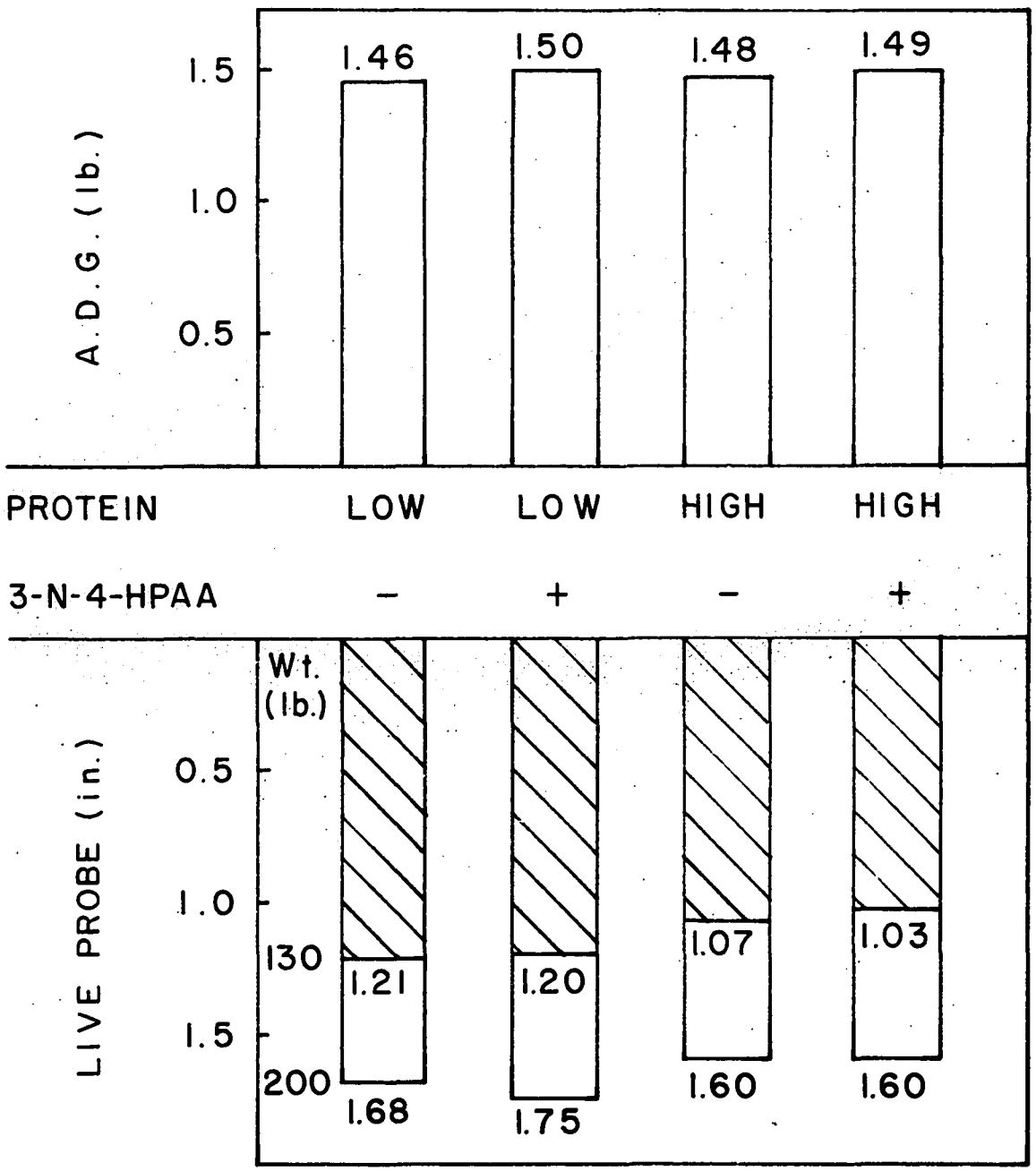
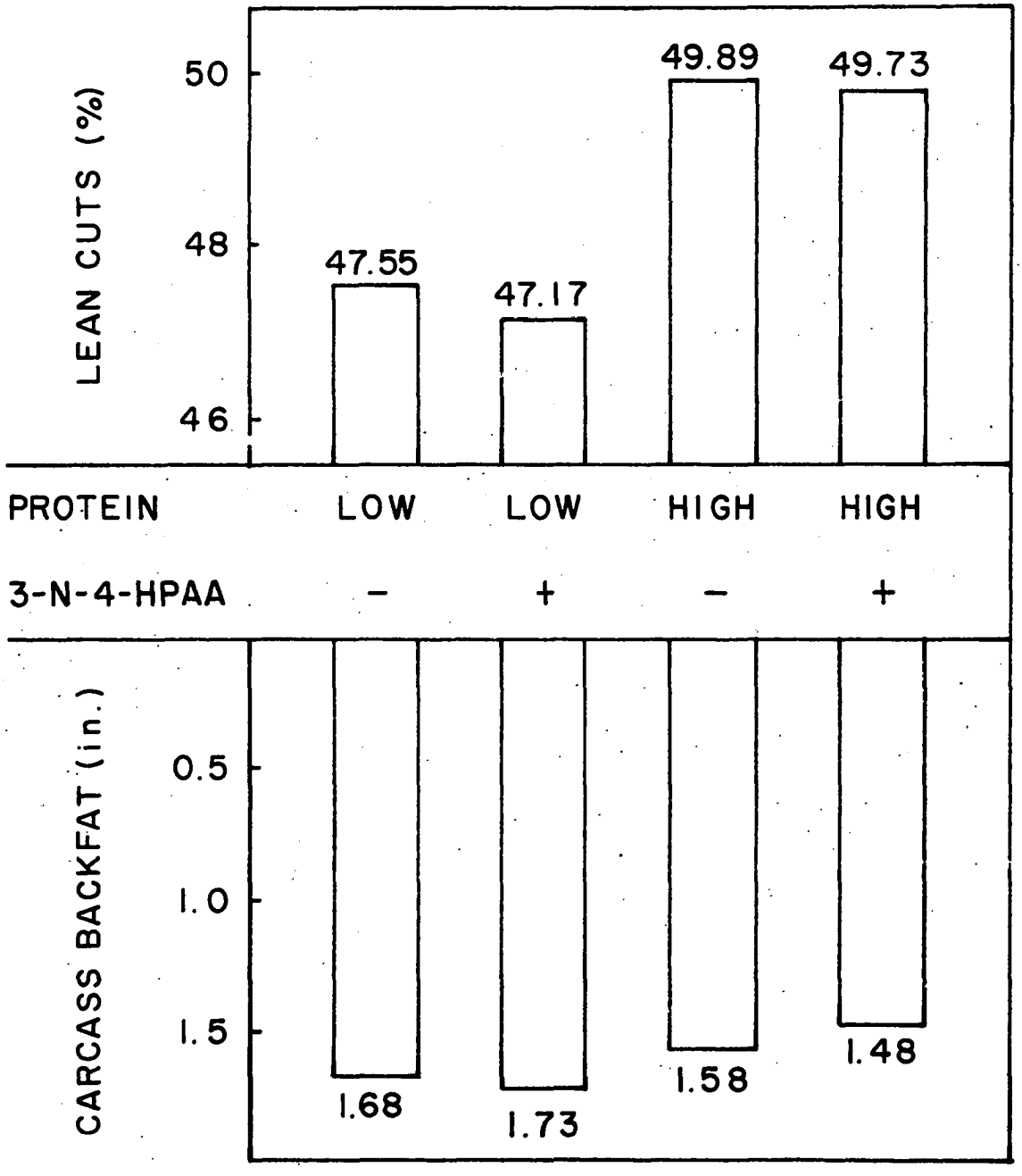

A.D.G. (lb.)
1.5
1.0
0.5
1.46
1.50
1.48
1.49
PROTEIN
LOW
LOW
HIGH
HIGH
3-N-4-HPAA
–
+
–
+
LIVE PROBE (in.)
Wt. (lb.)
0.5
1.0
130
1.5
200
1.21
1.20
1.07
1.03
1.68
1.75
1.60
1.60

Figure 4. Experiment 888 - Effects of 3-nitro-4-hydroxy-phenylarsonic acid and protein level on percent lean cuts and carcass backfat


LEAN CUTS (%)
50
48
46
47.55
47.17
49.89
49.73
PROTEIN
LOW
LOW
HIGH
HIGH
3-N-4-HPAA
–
+
–
+
CARCASS BACKFAT (in.)
0.5
1.0
1.5
1.68
1.73
1.58
1.48

fed in this experiment. In designing this trial it was anticipated that the "low" protein ration would be adequate to support normal growth. From the results it appears that rate of gain was not influenced by protein level; however, feed efficiency was significantly improved by feeding the "high" protein ration.

The "high" protein ration exerted a highly significant effect on carcass leanness as indicated by a reduction in the live probe at both 130 and 200 pounds body weight, decreased carcass backfat and a higher percent of lean cuts. This finding is in agreement with Robison et al. (1952), Wallace et al. (1954), Ashton et al. (1955) and Clausen (1960). It is possible that the effect of protein on carcass conformation in this experiment may have been somewhat exaggerated due to the higher energy level of the "low" protein ration. As can be seen from Table 5, the substitution of corn for soybean oil meal to reduce the protein level resulted in an increase in the productive energy level of the ration.

The arsenical, 3-N-4-HPAA, apparently had little effect on carcass leanness under the conditions of this experiment. However, carcass backfat was reduced when 3-N-4-HPAA was added to the "high" protein ration and a significant 3-N-4-HPAA x protein-level interaction was observed with respect to carcass backfat. This interaction did not occur in the case of other carcass measurements. Neither the live probe nor the percent lean cuts reflected the improvement in carcass lean-

ness that was indicated by the carcass backfat measurement.

Experiment 975 - Effect of 3-N-4-HPAA on gain, feed efficiency and carcass leanness when fed from three weeks of age to market weight

Objectives The purpose of this experiment was to see if the addition of 3-N-4-HPAA to the ration throughout the entire feeding period (from 10 to 200 pounds body weight) would improve carcass leanness in swine.

Procedure This experiment was conducted in cooperation with the Iowa State University Agricultural Engineering Department. In addition to the arsenical investigations, the effect of cycling temperatures on pig performance was studied. The experiment was conducted in Units G on concrete during the months of June to November. These units consist of nine houses. Each house was divided into four pens. The experiment included 108 pigs randomly allotted to the treatments arranged in a split-plot design. The basal ration was assigned to two pens in each house and the other ration treatment, basal plus 0.0025 percent 3-N-4-HPAA, was assigned to the two remaining pens in each house. Three houses were assigned to each of the three temperatures studied. The pigs were reallotted to the temperature treatments at the end of the fifth week and again at the end of the eleventh week of the experiment. However, the pigs remained on the same ration treatment throughout the entire experimental period.

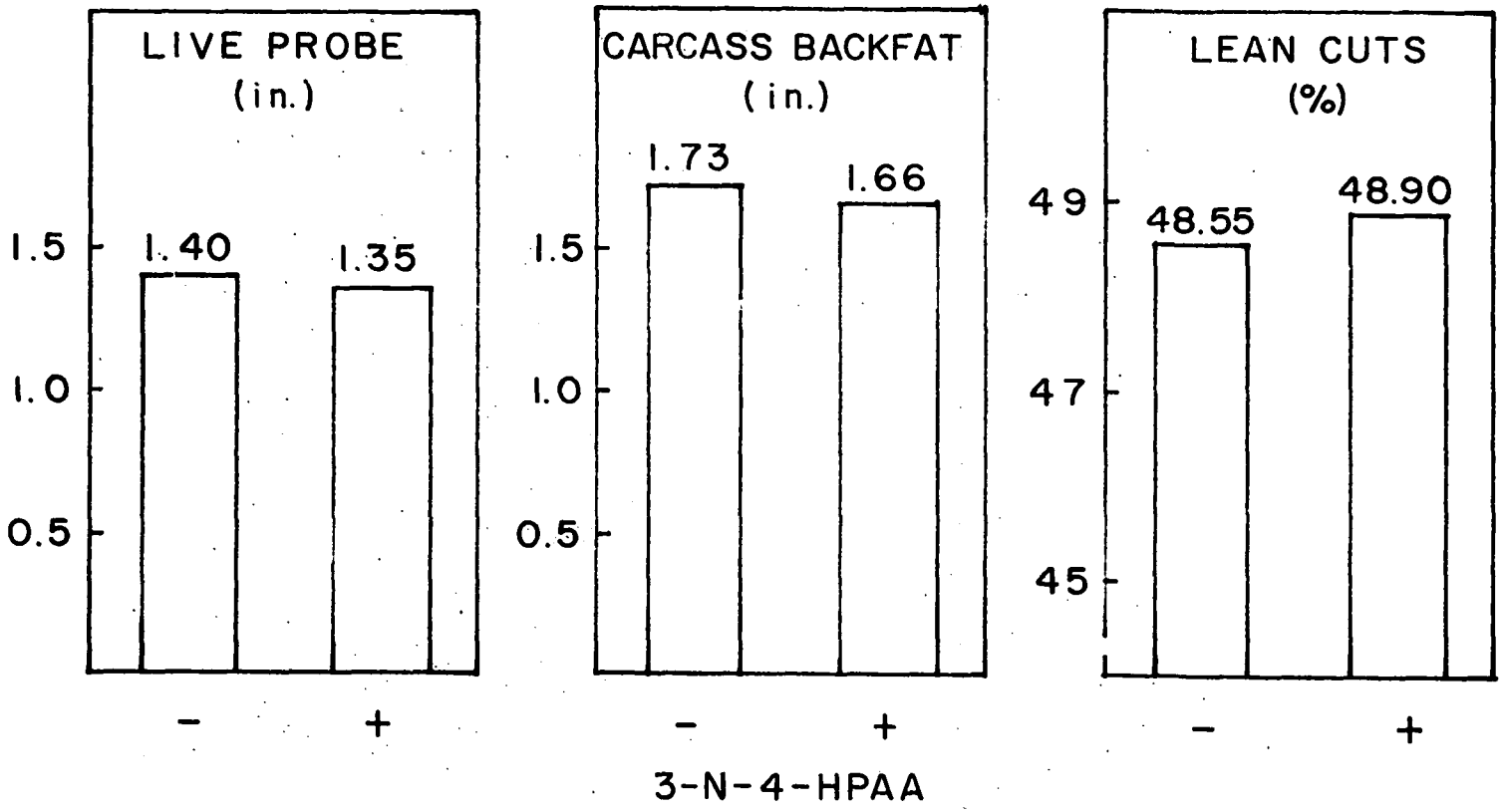
In the statistical analysis of the data, the experimental unit consisted of three pens of three pigs each on the same ration treatment, with each of these pens being from a different temperature treatment.

The average initial age was 20 days and the average initial weight was 11 pounds. The composition and the calculated analyses of the basal rations are presented in Tables 3 and 6, respectively. The starter ration was fed from the start to 40 pounds; the grower ration was fed from 40 to 105 pounds; and the finishing ration was fed from 105 pounds to approximately 200 pounds at which time live probes were taken and the pigs were slaughtered.

Results and discussion Summaries of average daily gain, feed required per pound of gain and carcass measurements are presented in Table 18. The analysis of variance plan and observed mean squares are found in Table 19. The treatment means for the carcass measurements are shown graphically in Figure 5.

The treatment means for average daily gain, feed efficiency, live probe, carcass backfat and percent lean cuts indicate an advantage for the addition of 3-N-4-HPAA to the basal ration. However, none of these differences were statistically significant. With the experimental design used there were only six replications of each of the two ration treatments. Consequently there were very few degrees of

Figure 5. Experiment 975 - Effects of 3-nitro-4-hydroxyphenyl-arsonic acid on live probe, carcass backfat and percent lean cuts


LIVE PROBE
(in.)
1.5
1.0
0.5
1.40
1.35
-
+
CARCASS BACKFAT
(in.)
1.73
1.66
1.5
1.0
0.5
-
+
LEAN CUTS
(%)
49
47
45
48.55
48.90
-
+
3-N-4-HPAA

freedom for making the test for statistical significance. From Table 18 one can see that in four of the six replications 3-N-4-HPAA increased the percent lean cuts, while in the other two replications the difference, although in favor of the basal ration, was less than one-tenth of one percent. With respect to carcass backfat, in four of the replications there was a substantial decrease in backfat when 3-N-4-HPAA was fed while there was essentially no difference in one replication and a definite advantage in favor of the basal group in one replication. When the effect of 3-N-4-HPAA on carcass backfat was analyzed statistically using the individual pig as the experimental unit, the difference in favor of the arsenical was statistically significant at the five percent level.

This experiment was not designed to assess the effect of temperature on carcass leanness. However, when one considered only the finishing period from the final allotment (approximately 105 pounds body weight) to market weight, it was noted that the percent lean cuts increased as the average temperature increased. With average temperatures of approximately 60, 70 and 78 degrees Fahrenheit the percent lean cuts were 48.21, 48.78 and 49.18, respectively.

Cod Liver Oil Studies

Experiment 941 - Effect of cod liver oil on carcass quality of growing-finishing swine

Objectives The purpose of this experiment was to see if cod liver oil was effective in improving carcass leanness and if so, what fraction of the oil was responsible for this effect.

Procedure The composition and the calculated analysis of the basal ration are found in Tables 3 and 6, respectively. Sixty crossbred pigs averaging 97 pounds body weight and 134 days of age were selected and randomly allotted from weight outcome groups to the five ration treatments. The restriction was placed on the allotment that no two littermate pigs would receive the same ration treatment. This experiment, conducted in dirt-dry-lots during the months of December to March, consisted of two replicated lots of six pigs per lot. The pigs were probed at approximately 200 pounds and then slaughtered.

The treatments were: 1) basal; 2) two percent cod liver oil; 3) four percent cod liver oil; 4) the saponifiable fraction equivalent in amount to that present in treatment 3; and 5) the non-saponifiable fraction added to the ration at the same level as would be present in the oil in treatment 3.

The saponification of the cod liver oil was carried out

in a 20-liter distillation flask. Heat was supplied by a heating mantle and was controlled by a rheostat.

Four liters of cod liver oil were placed in the flask. Approximately 700 grams of reagent grade potassium hydroxide were mixed with 10 liters of 95 percent ethanol and this mixture was added to the flask. The contents of the flask were mixed and then heated until most of the ethanol had distilled over. This ethanol was used in subsequent saponifications. The distillation required approximately six hours. The contents of the flask were then transferred to a five gallon carboy. Approximately six liters of distilled water were added to the carboy and mixed well. Two to three liters of hexane (Skelly-solve B) were mixed with the material in the carboy and set aside for separation of the non-saponifiable fraction. The top layer containing the non-saponifiable fraction was withdrawn with a suction apparatus. The material in the carboy was washed again with hexane as above. The non-saponifiable fraction was reduced in volume by distilling off most of the hexane for re-use. After the hexane layer was removed the contents of the carboy were acidified with HCl. Separation occurred immediately. The upper saponifiable layer was withdrawn, washed once with distilled water and stored until it was mixed in the ration.

The cod liver oil used in this experimental work was supplied by the New England By-Products Co., Boston, Massa-

chusetts and contained 85 I.U. of vitamin D_3 per gram and 1000 I.U. of vitamin A per gram. Therefore, additional vitamins A or D were not added to the rations containing either cod liver oil or the non-saponifiable fraction. The cod liver oil and the saponifiable fraction were substituted in the basal ration at the expense of corn starch; however, since the non-saponifiable fraction was reduced to a small volume, this was added to the basal ration without substitution for other ingredients in the ration.

Results and discussion Summaries of average daily gain, feed required per pound of gain and carcass measurements are presented in Table 20. The analysis of variance plan and observed mean squares are shown in Table 21.

The addition of the intact cod liver oil to the ration at both the two and four percent levels resulted in slightly faster gains and a rather marked improvement in feed efficiency. The improvement in feed efficiency can probably be attributed to the higher energy content in the cod liver oil rations. The saponifiable ration appeared to be somewhat unpalatable. This was indicated by the reduced feed intake particularly during the latter stage of the experiment.

Loins from pigs on each treatment were roasted and subjected to a taste panel evaluation. Contrary to the observations reported by Worden (1958) a very distinct fishy flavor was noted particularly in the meat from pigs fed four percent

cod liver oil and those fed the saponifiable fraction. As would be expected no off-flavor was detected in the meat from pigs fed the non-saponifiable fraction.

The percent lean cuts was increased nearly one percentage unit when the saponifiable fraction was fed. This advantage was not apparent in the case of the live probe or the carcass backfat measurement. The addition of cod liver oil to the ration appeared to increase carcass leanness, as measured by percent lean cuts, in the first replication. However, when both replications are averaged and live probe, carcass backfat and lean cuts were considered, it could be concluded that cod liver oil was ineffective in increasing carcass leanness in swine under the conditions of this experiment.

Experiment 962 - Effect of cod liver oil on carcass quality of growing-finishing swine

Objectives The carcass data collected during the first few weeks of the slaughtering period in Experiment 941 indicated that cod liver oil, particularly at the two percent level, might be effective in producing a leaner carcass in swine. Therefore, Experiment 962 was initiated before the termination of Experiment 941. The purpose of this experiment was to study the effect of three added levels of cod liver oil on carcass quality.

Procedure The composition and calculated analysis of

the basal ration are shown in Tables 3 and 6, respectively. This ration is very similar to that used in Experiment 941. Seventy-two pigs averaging 107 days of age and 108 pounds body weight were randomly allotted from littermate outcome groups to four ration treatments: 0, 1.0, 2.0 and 3.0 percent cod liver oil. This experiment was conducted in dirt-dry-lots during the months of March to May.

Because of the rather definite fishy taste noted in the meat from pigs fed four percent cod liver oil in Experiment 941, it was decided to place the pigs on the three percent cod liver oil ration on the basal ration for two to three weeks after they reached 200 pounds prior to marketing. Therefore the live probe was the only measure of fatness obtained on the pigs from this treatment. All other pigs were slaughtered at approximately 200 pounds body weight and carcass data were collected.

The cod liver oil used in this experiment was from the same source as that used in Experiment 941.

Results and discussion The summaries of gain, feed efficiency and carcass measurements are presented in Table 22. The analysis of variance plan and observed mean squares are shown in Tables 23 and 24.

The addition of cod liver oil to the ration resulted in a slight improvement in rate of gain and a significant improvement in feed efficiency. No significant effect existed

between treatments with respect to any of the carcass traits measured. The pigs fed the oil actually yielded a slightly lower percent of lean cuts than the pigs on the basal ration.

Results of taste panel studies with loins from pigs on this experiment revealed a slight fishy taste in the meat from pigs fed two percent cod liver oil. Very little, if any off-flavor could be detected in the meat from those pigs fed the one percent cod liver oil ration.

Styramate Studies

The trade name for this compound which was developed by the Armour Pharmaceutical Co., Kankakee, Illinois is Sinaxar. The chemical name is 2-hydroxy-2-phenyl ethyl carbamate. Styramate is a centrally-acting muscle relaxant. It induces relaxation of skeletal muscle by interruption of nerve transmission in the spinal cord and brain stem rather than by exerting a blocking effect at the junction between the motor nerves and the muscles (Chesrow et al., 1960). These workers also reported that styramate is well absorbed in the gastrointestinal tract and exerts its effect on the central nervous system within 15 minutes after oral administration.

Experiment 987 - Levels of styramate for growing-finishing swine

Objectives The purpose of this experiment was to investigate the possibility of affecting carcass leanness with

varying levels of styramate.

Procedure This experiment was conducted during the period from July to December in dirt-dry-lots. Seventy-two crossbred pigs were randomly allotted to six ration treatments from littermate outcome groups. The restriction was placed on the allotment that the sex of the pigs would be equalized between treatments as nearly as possible. The ration treatments were as follows: 0, 50, 100, 200, 400 and 800 milligrams of styramate per pound of ration. The composition and calculated analyses of the basal rations are found in Tables 3 and 6, respectively. The growing ration was fed from approximately 35 to 125 pounds body weight at which time the pigs were placed on the finishing ration.

The pigs were weighed at four week intervals. Live probes were taken when the pigs averaged 110 pounds body weight and again at 200 pounds. As the individual pigs reached approximately 200 pounds they were slaughtered and carcass data were collected.

Results and discussion Summaries of average daily gain, feed required per pound of gain and carcass measurements are presented in Table 25. Table 26 shows the analysis of variance plan and the observed mean squares for these data. The treatment means for average daily gain, feed efficiency and carcass measurements are illustrated graphically in Figures 6, 7 and 8.

Figure 6. Experiment 987 - Effects of levels of styramate on average daily gain and feed required per pound of gain

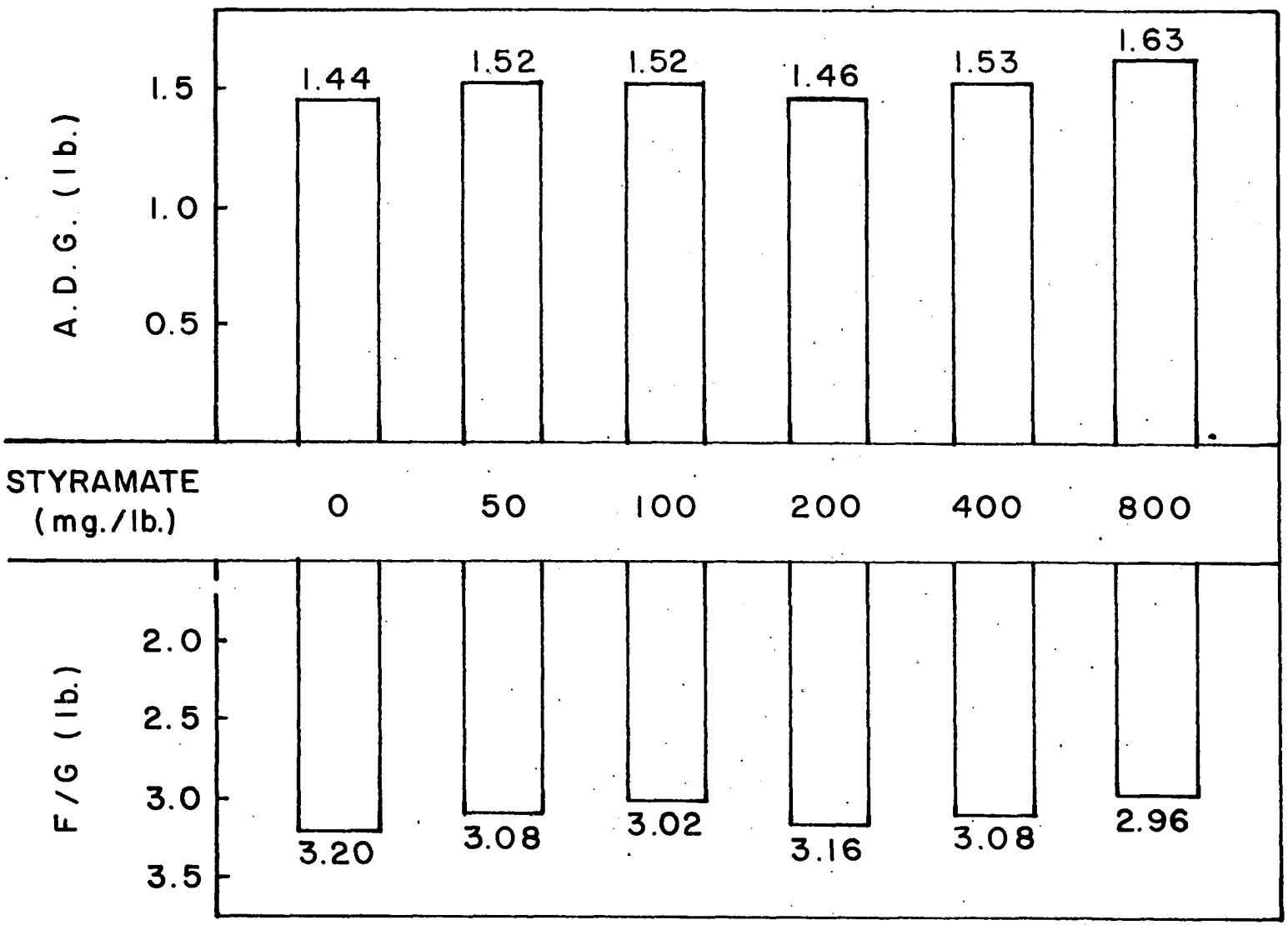

A.D.G. (lb.)
1.5
1.0
0.5
1.44
1.52
1.52
1.46
1.53
1.63
STYRAMATE
(mg./lb.)
0
50
100
200
400
800
F/G (lb.)
2.0
2.5
3.0
3.5
3.20
3.08
3.02
3.16
3.08
2.96

Figure 7. Experiment 987 - Effects of levels of styramate on loin eye area and on live probe taken at 110 and 200 pounds body weight

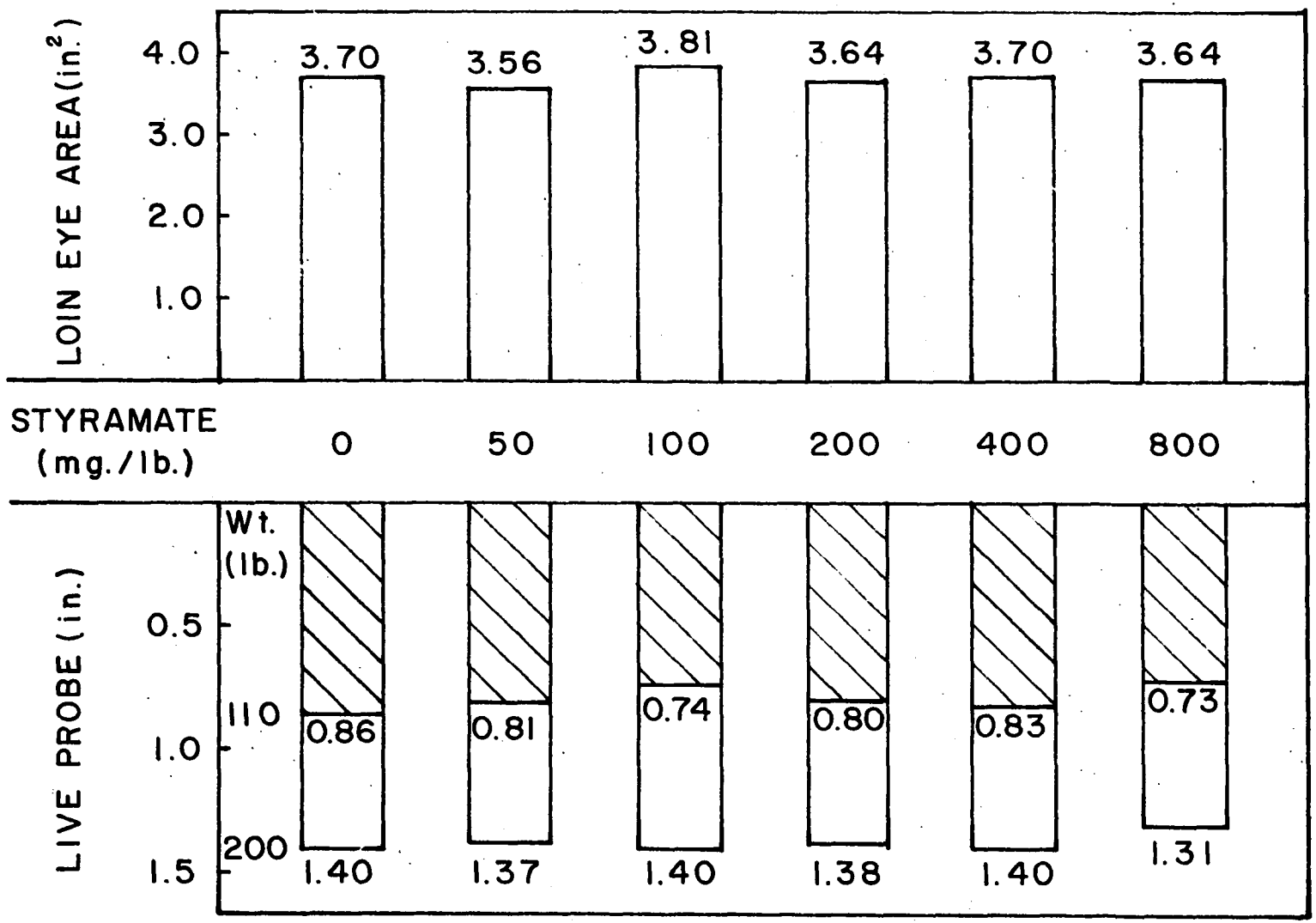
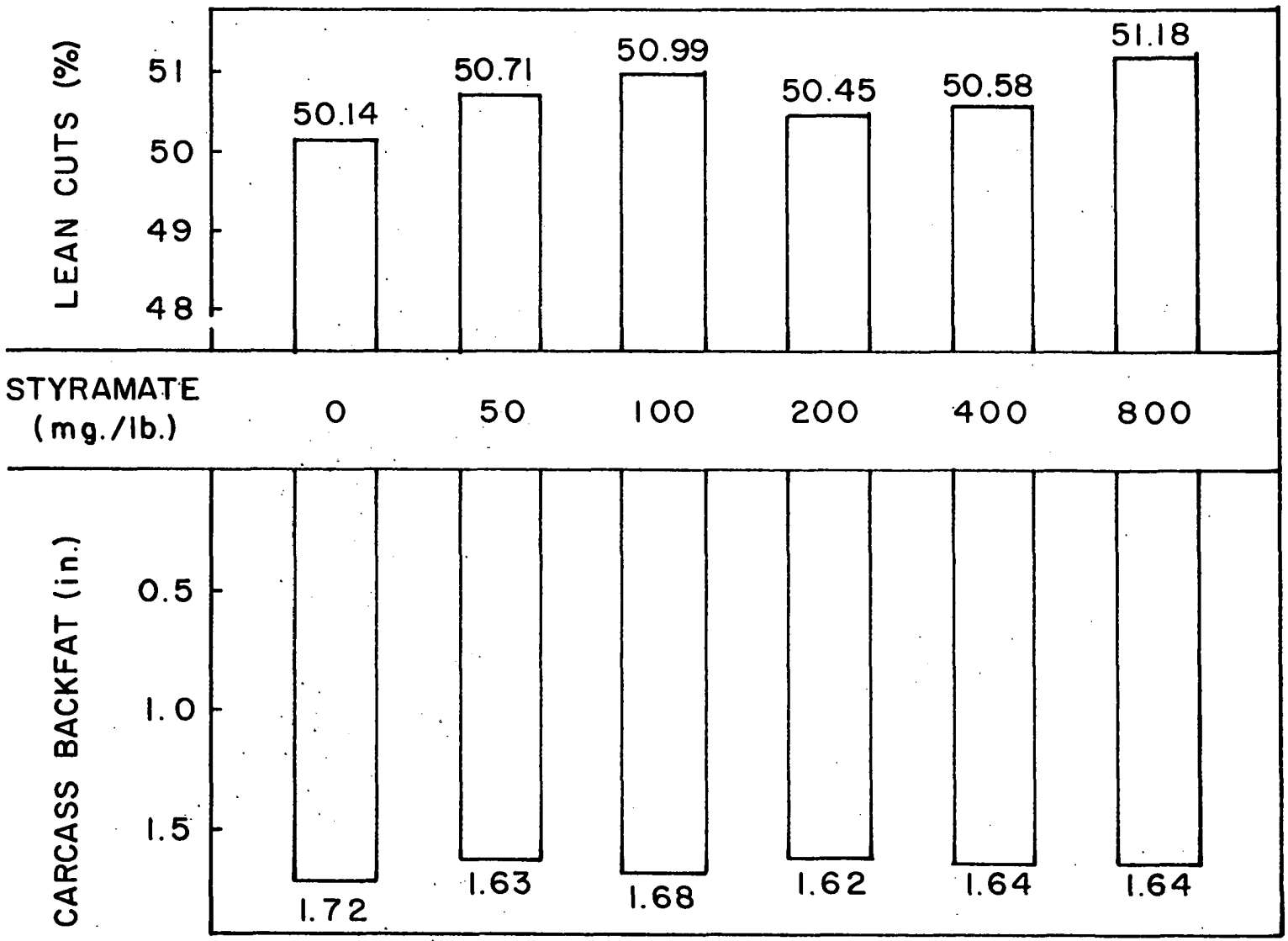

LOIN EYE AREA(in.²)
4.0
3.0
2.0
1.0
3.70
3.56
3.81
3.64
3.70
3.64
STYRAMATE (mg./lb.)
0
50
100
200
400
800
LIVE PROBE (in.)
Wt. (lb.)
0.5
1.0
1.5
110
200
0.86
0.81
0.74
0.80
0.83
0.73
1.40
1.37
1.40
1.38
1.40
1.31

Figure 8. Experiment 987 - Effects of levels of styramate on percent lean outs and carcass backfat


LEAN CUTS (%)
51
50
49
48
50.14
50.71
50.99
50.45
50.58
51.18
STYRAMATE (mg./lb.)
0
50
100
200
400
800
CARCASS BACKFAT (in.)
0.5
1.0
1.5
1.72
1.63
1.68
1.62
1.64
1.64

Seven pigs were removed during the course of this experiment because of either death or sickness. Pigs of comparable weight and age were substituted for five of the pigs that were removed during the early stages of the experiment. No replacements were made for the others.

The addition of styramate to the ration resulted in a significant linear improvement with respect to average daily gain and feed efficiency. Although the live probes taken at 110 pounds indicated that the styramate-fed pigs were somewhat leaner than the controls, this effect was not statistically significant. The live probes taken at 200 pounds body weight revealed a significant decrease in backfat with the addition of styramate to the ration.

The carcass backfat measurements suggested that the feeding of the muscle-relaxant was effective in reducing backfat; however, there appeared to be no response related to the level of the drug. Apparently 50 milligrams of styramate per pound of ration was as effective in reducing carcass backfat as were the higher levels. The results of the loin eye measurements were very erratic with no apparent pattern relative to the ration treatments.

When styramate was fed there was a significant increase in the percent of lean cuts. Most of this treatment effect was due to the highly significant linear regression. The highest level of styramate (800 milligrams per pound) resulted

in the highest percent lean, as measured by the weight of the lean cuts, in this experiment. There was a high degree of uniformity between replications in percent lean cuts with an observed coefficient of variation of only 0.56.

It is interesting to note in this experiment that the decrease in backfat was not accompanied by a decrease in dressing percent as was shown in the work by Whatley et al. (1953).

Experiment 1033 - Styramate for growing-finishing swine

Objectives The results obtained in Experiment 987 suggested that styramate was effective in producing a leaner carcass in swine without sacrificing rate of gain or feed efficiency. The data on average daily gain, feed conversion and percent lean cuts indicated that the highest level tested in Experiment 987 (800 milligrams per pound of ration) gave the best results. The purpose of this experiment was to further test the two higher levels of styramate fed in Experiment 987 and to also investigate the effects of a higher level of styramate than that fed in the previous experiment.

Procedure The procedures followed in this experiment were essentially identical to those in Experiment 987. Seventy two pigs averaging 44 pounds body weight and 60 days of age were randomly allotted from littermate outcome groups to the four ration treatments in the same dirt-dry-lots as were

used for Experiment 987. The levels of styramate fed were 0, 400, 800 and 1200 milligrams per pound of ration. The composition and calculated analyses of the basal rations are found in Tables 3 and 6, respectively. The experimental period was from January to May.

Live probes were taken at 200 pounds body weight at which time the pigs were slaughtered and carcass data were collected.

Results and discussion Summaries of average daily gain, feed required per pound of gain and carcass measurements are presented in Table 27. Figures 9 and 10 illustrate graphically the results of this experiment. The analysis of variance plan and the observed mean squares are shown in Table 28.

Contrary to the findings in Experiment 987, rate of gain was depressed when styramate was added to the ration. This depression was of a relatively small magnitude; however, the effect was noted in all three replications and the linear regression was statistically significant. There were no consistent differences between treatments in the live probe measurements. In all replications carcass backfat was thickest in the pigs fed 800 milligrams of styramate per pound of ration. This resulted in a significant quadratic regression and also a significant cubic regression in the statistical analysis of the carcass backfat measurements. The reason for this effect is not clear.

Figure 9. Experiment 1033 - Effects of levels of styramate on loin eye area and live probe

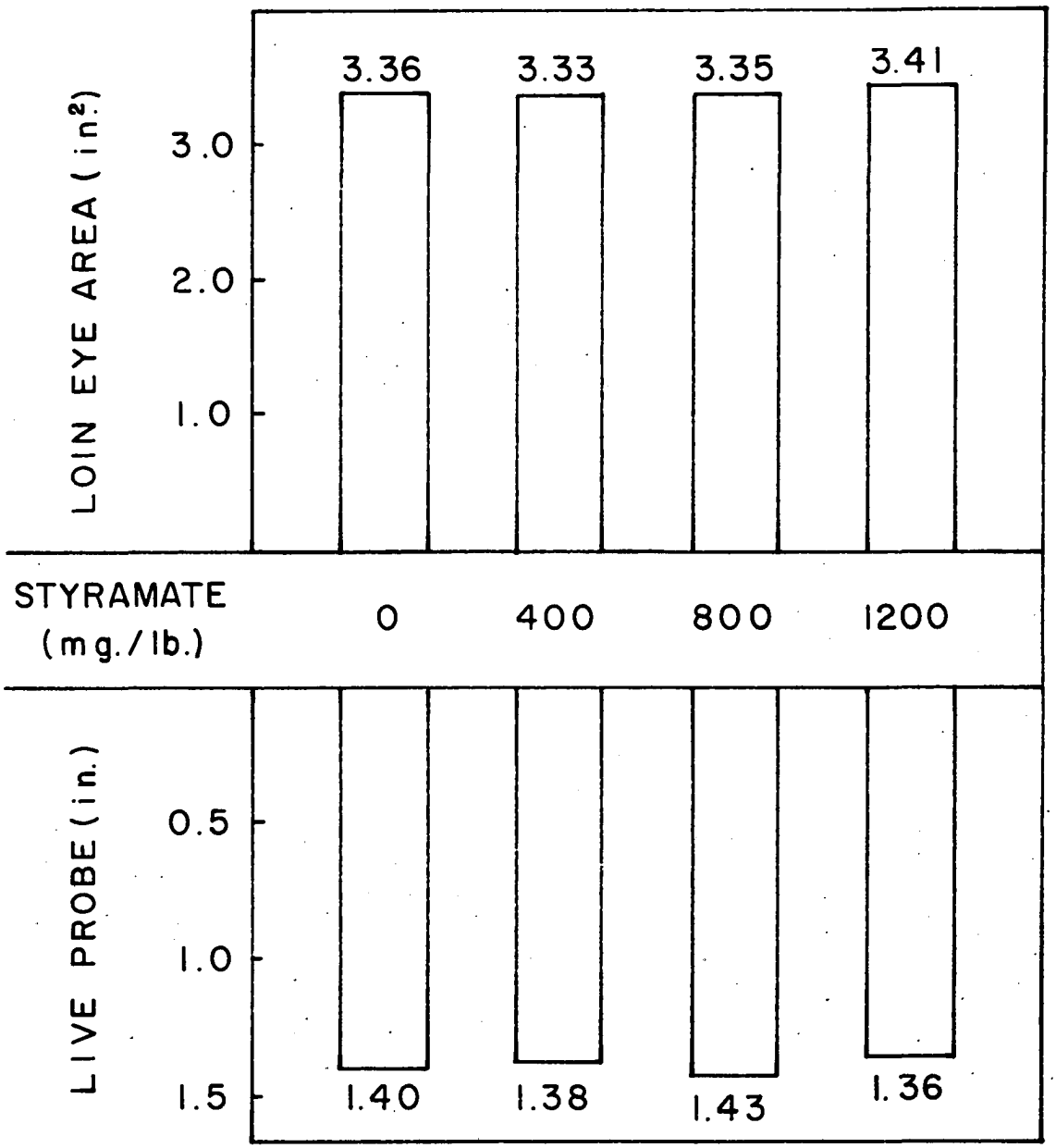
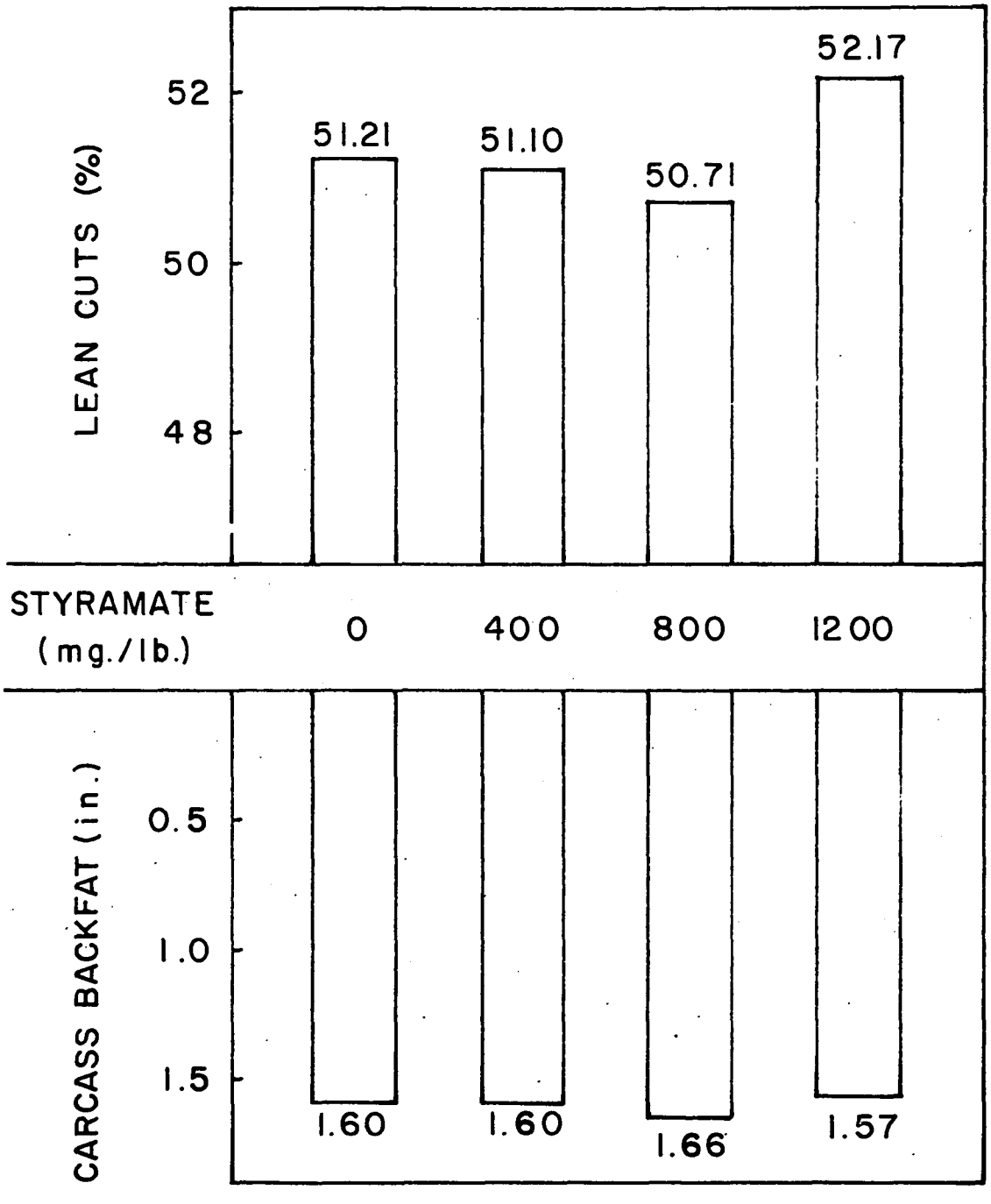

LOIN EYE AREA (in.²)
3.0
2.0
1.0
3.36
3.33
3.35
3.41
STYRAMATE (mg./lb.)
0
400
800
1200
LIVE PROBE (in.)
0.5
1.0
1.5
1.40
1.38
1.43
1.36

Figure 10. Experiment 1033 - Effects of levels of styramate on percent lean cuts and carcass backfat


LEAN CUTS (%)
52
50
48
51.21
51.10
50.71
52.17
STYRAMATE
(mg./lb.)
0
400
800
1200
CARCASS BACKFAT (in.)
0.5
1.0
1.5
1.60
1.60
1.66
1.57

In the first two replications there was an increase in the area of the logissimus dorsi muscle measured at the tenth rib when styramate was fed; however, the reverse was true in the third replication. There was no significant effect on percent lean cuts due to treatment. However, in all three replications the pigs fed the highest level of styramate yielded the highest percent of lean cuts.

Experiment 1051 - Styramate for growing-finishing swine

Objectives The results of Experiment 1033 were not in agreement with those observed in the previous styramate trial, Experiment 987. Since there was an apparent depression in growth rate with the higher level (1200 milligrams per pound of ration) of styramate in Experiment 1033, this experiment was designed to reinvestigate levels of styramate that had been used in Experiment 987.

Procedure The procedures followed in this experiment were essentially the same as those employed in the two previous styramate trials, except the pigs in this experiment were fed on concrete. This experiment was conducted on concrete during the months of March through June. Eighty crossbred pigs averaging 53 pounds body weight and 65 days of age were randomly allotted from littermate outcome groups to the five ration treatments. The five levels of the drug studied were 0, 100, 200, 400 and 800 milligrams of styramate per

pound of ration. The composition and calculated analyses of the basal rations are found in Tables 3 and 6, respectively.

Results and discussion Summaries of average daily gain, feed required per pound of gain and carcass measurements are presented in Table 29. The analysis of variance plan and the observed mean squares are shown in Table 30.

There was a slight improvement in rate of gain when styramate was added at 100, 200 and 400 milligrams per pound of ration. The quadratic regression was statistically significant. The feed conversion data were very erratic with only the 100 and 400 milligram levels showing an improvement over the basal.

The only significant effect with respect to the live probe measurements was a highly significant effect between replications. This difference can probably be attributed to a breed difference. Replications one and three were predominantly Landrace x Yorkshire crossbred pigs while the other two replications included pigs with some Farmer's Hybrid breeding. There was no consistent pattern between treatments in backfat thickness.

Although the average loin eye area was largest from pigs on the basal ration, the differences were not statistically significant. It is difficult to interpret the percent lean cuts data in this experiment. The average of the four replications indicates a substantial advantage in favor of the

basal ration in yield of lean cuts. This advantage is mainly due to the differences in the fourth replication. In this replication the pigs from the basal ration yielded a considerably higher percent lean cuts than the styramate-fed pigs. In this experiment there appeared to be no consistent relation between the level of styramate fed and carcass leanness.

Experiment 1050 - Effect of styramate and growth hormone on plasma unesterified fatty acid (UFA) levels in swine

Objectives This study was undertaken to determine if a similarity existed between growth hormone and styramate in their effect on the plasma UFA levels in swine. Also this experiment was designed to ascertain if there was a difference in plasma UFA levels between boars, barrows and gilts.

Procedure Twenty-two three week old crossbred pigs were selected from three litters and placed on a conventional pig starter ration. It was originally planned that three boars, three barrows and three gilts would be selected from each of two litters. This would have provided for one of each sex from each litter to be assigned to each of the following treatments: 1) control, 2) bovine growth hormone and 3) styramate. However, due to limitations in litter size, it was necessary to make some substitutions from a third litter. The barrows were castrated at four weeks of age. The pigs were confined on concrete in a small pen in which they had

free access to feed and water at all times. The pigs remained in the same pen from weaning until the experiment was terminated. Live probes were taken when the pigs averaged 165 pounds body weight. When the pigs were approximately four months of age and averaged 180 pounds, they were randomly assigned from littermate outcome groups to the experimental treatments. The treatments were administered in daily intramuscular injections for one week. Blood samples were taken from the tail. The blood was collected in 15 milliliter centrifuge tubes to which had been added 0.5 milliliters of saturated sodium oxalate. The sodium oxalate was dried in the tube. Approximately eight milliliters of blood were collected and the tubes were placed in a box containing a layer of crushed ice. The blood samples were taken to the laboratory as soon after collection as possible for plasma UFA determinations. The samples were centrifuged at 1800 r.p.m. for ten minutes and plasma samples were analyzed in duplicate for UFA by the method of Dole (1956). The elapsed time from bleeding until the extract was prepared was approximately 1.5 hours.

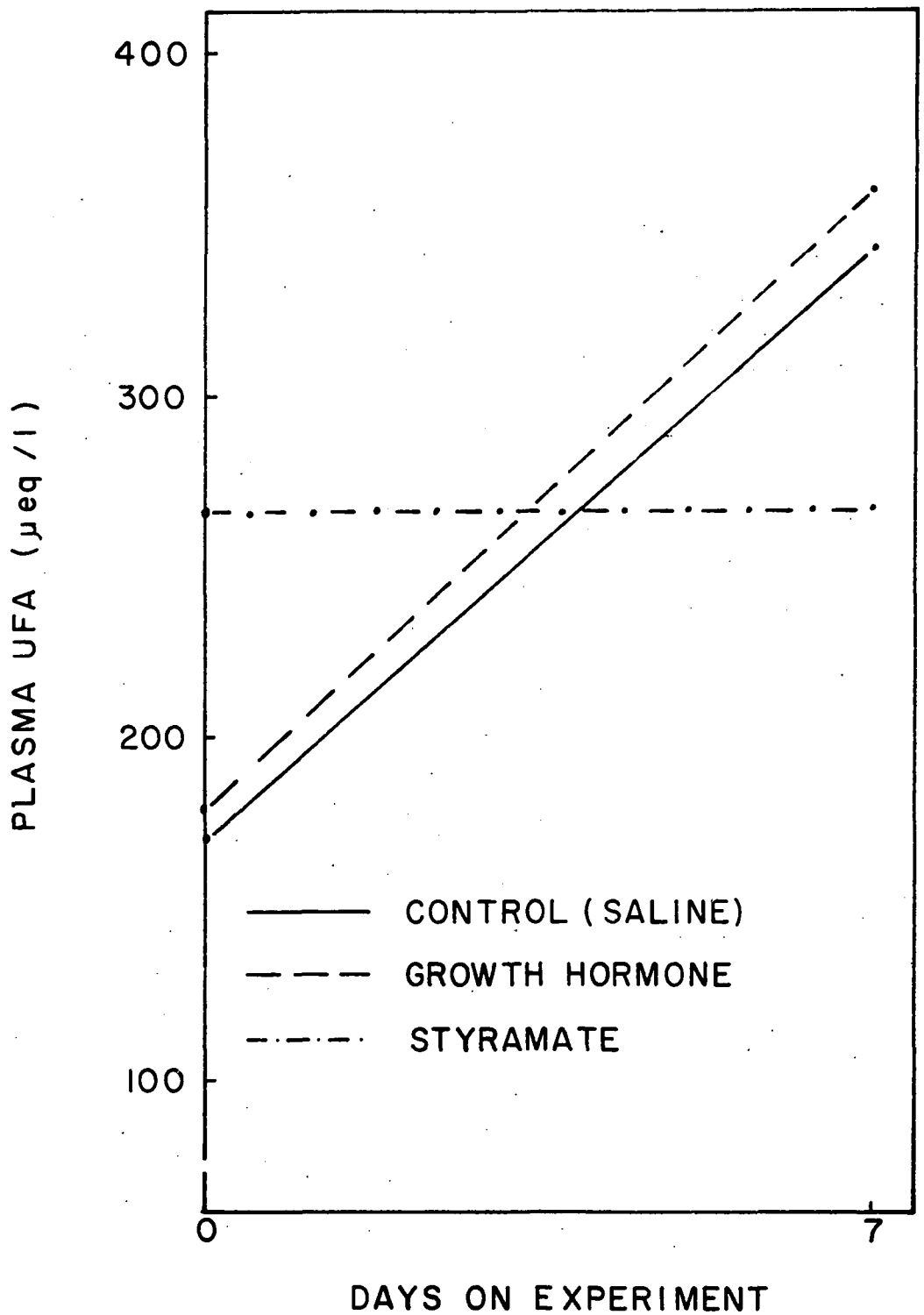
One day prior to the start of the experimental treatments the pigs were bled for an initial UFA determination. Since Gordon and Cherkes (1956) showed a rise in UFA levels in humans with fasting up to six hours, feed was withdrawn at 11:00 p.m. the night before the blood samples were taken.

The pigs were given access to feed from 7:00 to 8:00 a.m. on the day of bleeding and then the feed was again withdrawn until the blood samples were collected at 2:00 p.m. The treatments were administered each morning at 8:00 a.m. The bovine growth hormone, dissolved in sterile saline, was given daily at the rate of 133 micrograms of growth hormone per kilogram of body weight. Styramate, dissolved in sesame oil, was administered at the rate of 5 milligrams per kilogram of body weight per day. The control animals were injected daily with sterile saline in order to simulate all experimental procedures as closely as possible.

Results and discussion Summaries of the individual pig data are presented in Table 31. Figure 11 illustrates graphically the change in UFA levels on each treatment. The analysis of variance plan and the observed mean squares for the UFA data are shown in Table 32.

Engel et al. (1959) reported that intravenous injection of human growth hormone to both hypophysectomized and normal individuals caused an increase in plasma UFA six hours after injection. Raben and Hollenberg (1958) showed that human growth hormone raised fasting values in normal and hypopituitary human subjects. This effect lasted for at least 24 hours in hypopituitary subjects and for a shorter period in normal subjects. However, porcine and bovine growth hormone preparations did not affect the fatty acid level in human

Figure 11. Experiment 1050 - Effects of daily injections of growth hormone and styramate on plasma unesterified fatty acid levels


400
300
200
100
PLASMA UFA (μeq / l)
CONTROL (SALINE)
GROWTH HORMONE
STYRAMATE
0
7
DAYS ON EXPERIMENT

subjects.

In this experiment the change in the UFA level of pigs injected with bovine growth hormone did not differ significantly from the change observed in the control group. One pig in the control group (7318) differed by more than two standard deviations from the mean with an unusually large increase in the UFA level during the experimental period. When the value for this pig is omitted from the data, the increase in the UFA level in the growth hormone group is nearly double the increase observed in the control group. The reason for the rise in UFA levels in the control group is not entirely clear. Gordon and Cherkes (1956) showed that the administration of epinephrine to humans resulted in an immediate rise in UFA levels in humans. This rise occurred within a 20 minute period, but the elevation was short-lived. In this experiment the pigs appeared to be much more excited during the final bleeding. This may have resulted in a greater secretion of epinephrine and in turn a higher level of plasma UFA.

The increase in the plasma UFA levels in the styramate group during the experimental period was significantly less than that in the control and growth hormone groups. One can only speculate in attempting to explain the effect of styramate on the UFA levels. In Experiment 987 the styramate-fed pigs gained faster and yielded a significantly higher per-

centage of lean cuts than the control group. This might suggest the possibility of an increased amount of growth hormone being produced by the styramate-fed pigs. Engle et al. (1958) has postulated that the rise in UFA in rats following growth hormone injections may provide an important source of energy necessary for the known protein anabolic effect of growth hormone. Therefore, one might expect the increase in UFA levels to be greater in the styramate group than in the controls which was not the case in this experiment. The effect of styramate injections on the UFA levels might be explained by a decreased secretion of epinephrine due to the administration of the muscle relaxant.

No difference in plasma UFA levels was noted between sexes in this experiment.

The results of the live probes taken at 165 pounds body weight indicated that boars were leannest and barrows the fattest of the three sexes. The adjusted probes for the boars, gilts and barrows were 0.97, 1.16 and 1.20 inches, respectively. This is in agreement with the work of Zobrisky et al. (1959).

GENERAL DISCUSSION

Arsenical Studies

In Experiment 811, in which the pigs used were extremely uniform with respect to breeding, initial weight, and growth rate within replication, the addition of three levels of 3-N-4-HPAA to the basal ration decreased backfat as measured by the live probe at 115 and 200 pounds body weight. At 115 pounds pigs fed 3-N-4-HPAA at levels of 0.0025, 0.005 and 0.01 percent of the ration showed a decreased backfat of 11, 13 and 11 percent, respectively, when compared with the basal group. When the three arsenical levels were pooled for statistical analysis and compared to the controls, this effect was significant. At 200 pounds all levels of 3-N-4-HPAA again reduced backfat. However, the percentage decrease was of a smaller magnitude than that observed at the lighter weight. The fact that the live probes taken at both weights showed similar differences between the control group and the three treated groups gives added confidence to the probability that a difference did exist between treatments. However, this fact also suggests that the difference between treatments occurred mainly prior to the time the pigs reached 115 pounds body weight.

Three subsequent experiments were conducted with 3-N-4-HPAA in which additional methods were used to measure carcass

leanness. The results of these three experiments were somewhat inconsistent and failed to substantiate completely the findings in Experiment 811. The only indication of a leaner carcass with the addition of 3-N-4-HPAA in Experiment 877 was a slight, but nonsignificant, decrease in live probe at 140 and 200 pounds body weight. Although there is likely to be some variation in the trimming of the lean cuts, the percent lean cuts probably gives the best measure of the amount of muscling in a pig of any of the measurements used in this study. This measurement failed to show any significant difference due to treatment in this experiment.

The feeding of a "high" protein ration in Experiment 888 resulted in a highly significant improvement in carcass leanness in all four measurements used -- live probe at both 130 and 200 pounds body weight, carcass backfat measured at the packing plant and percent lean cuts. The "low" protein ration used in this experiment was adequate for normal growth if body weight gain is used as the sole criterion for nutritional adequacy. The difference in live probes between protein levels was greater at 130 pounds than at 200 pounds. This supports the observation by Kropf et al. (1959) that muscle development in swine is more severely hindered in early growth than in later growth by a low protein ration. When one considers the higher cost of the "high" protein ration and the reduced dressing percent when this ration was fed, there

was no economic advantage in feeding the "high" protein ration if the producer was selling the hogs on a grade and yield basis. In this experiment there was a significant 3-N-4-HPAA x protein interaction with respect to carcass backfat. The addition of the arsenical to the "high" protein ration resulted in one tenth of an inch decrease in backfat. This indicates that, if 3-N-4-HPAA feeding does produce a leaner carcass, the effect of 3-N-4-HPAA on the carcass is not due to a "protein-sparing" effect since one would expect the sparing effect to be more apparent on a low protein ration than on a high protein ration. The addition of 3-N-4-HPAA to the ration in this experiment resulted in a highly significant improvement in dressing percent.

In Experiment 975 in which 101 pigs were slaughtered, there was a tendency for the arsenical-fed pigs to be leaner as measured by the live probe, carcass backfat and percent lean cuts. However, these differences were not statistically significant. In this experiment the pigs were started on the experimental treatments at approximately three weeks of age. The arsenical-fed pigs gained faster and were more efficient in feed conversion throughout the entire experimental period than the controls. Carcass backfat was inversely associated with rate of gain in this experiment as was shown by the correlation coefficient of -.38. However, percent lean cuts was also negatively associated with rate of gain with a cor-

relation coefficient of -.21.

In each of the four experiments conducted to study the effect of 3-N-4-HPAA on carcass leanness, there was some evidence which indicated that arsenical-fed pigs were slightly leaner than the controls. However, this difference, if real, is quite small and the techniques used in this study for measuring carcass leanness are not sensitive enough to show a consistent response in favor of the arsenical.

Cod Liver Oil Studies

The feeding of cod liver oil in Experiments 941 and 962 failed to increase carcass leanness as measured in these studies. This is not in agreement with the work of Worden (1958).

There was no significant effect with respect to rate of gain when cod liver oil was fed; however, feed efficiency was improved when the oil was included in the ration. This latter effect was significant in Experiment 962. The effect on feed conversion was probably due partly to the higher energy content of the cod liver oil rations. The gain and feed efficiency data in these two experiments are in line with the results reported by Worden (1958).

These studies suggested that there may be a factor(s) in the saponifiable fraction which would affect carcass leanness. This might be explained by the observation of Maynard and

Loosli (1956) that a specific factor found in the saponifiable fraction of cod liver oil was responsible for lowering the fat percentage of milk from dairy cows fed cod liver oil. However, the carcass data in Experiment 941 revealed that the saponifiable fraction resulted in a greater improvement in lean cuts than in live probe or carcass backfat. This suggests that if there is an effect from the saponifiable fraction it is more a result of increasing muscle development than it is of inhibiting fat synthesis.

Contrary to the findings of Worden (1958), cod liver oil when fed at levels as high as two percent of the ration imparted a distinct fishy odor and flavor to the meat from these pigs. The off-flavor was much more prevalent in the fat than in the lean meat. Meat from pigs fed either four percent cod liver oil or the saponifiable fraction was particularly objectionable with respect to flavor and odor.

Styramate Studies

Three experiments were conducted to evaluate the effect of styramate on carcass leanness. In Experiment 987 the addition of styramate to the ration resulted in faster gains with less feed required per pound of gain. The linear regression for each of these effects was statistically significant. In this experiment the live probes taken at both 110 and 200 pounds body weight indicated the styramate-fed pigs were

leaner. The difference in the live probes between the control group and the styramate-fed pigs was slightly greater at 110 pounds than at 200 pounds. This early response to styramate in reducing backfat may have been associated with differences in the shape of the growth curves of the treated pigs compared with the controls. Styramate stimulated gains during the first four week period. During the second four week period there was a slight depression in rate of gain when styramate was fed. Then during the third four week period all levels of styramate stimulated gains. According to McMeekan and Hammond (1940), rapid early growth intensifies the early developing tissues (bone and muscle) and inhibits the later developing tissues (subcutaneous fat). Thus one might expect a greater difference in backfat between the controls and the styramate-fed pigs at 110 pounds than at 200 pounds at which time the treated pigs were growing considerably faster than the controls.

Considering the entire experimental period, rate of gain was negatively associated with carcass backfat. The correlation coefficient between rate of gain and carcass backfat was -.23, while the correlation coefficient between rate of gain and percent lean cuts was .03.

The addition of styramate to the ration increased percent lean cuts in Experiment 987. The linear regression for lean cuts on styramate levels was highly significant.

Two subsequent experiments failed to substantiate fully the findings in Experiment 987. In Experiment 1033 styramate depressed rate of gain and feed efficiency. On the first replication the pigs gained considerably faster than the other two replications and in this case all levels of styramate increased percent lean cuts compared with the basal ration. Only on the highest level of styramate (1200 milligrams per pound of ration) was there a consistent improvement in percent lean cuts when styramate was added to the ration.

In Experiment 1051 the three lower levels of styramate improved gains slightly; however, this effect was not consistent in all replications. The carcass data in this experiment were very erratic with much variation existing between replications. There was no indication in this experiment that styramate increased carcass leanness.

The reason for the inconsistent effect of styramate on carcass leanness in these studies is not clear. The calculated analyses of the rations were identical in all three of these experiments. The breeding of the pigs was essentially the same for all experiments. One possible explanation for the variable response could be the differences in environmental temperatures between experiments. There was no noticeable effect on the activity of the pigs when the muscle relaxant was added to the ration. However, if this drug did cause muscle relaxation at the levels fed, one could speculate

that a decreased activity during hot weather might result in faster, more efficient gains. Since in Experiment 987 (which was initiated in July) rate of gain was negatively correlated with depth of backfat, any factor contributing to faster growth, particularly early in the growing period, might also contribute to the production of a leaner carcass. Experiments 1033 and 1051 were initiated in January and March, respectively. In neither of these experiments was there a substantial growth response on the styramate rations early in the experimental period as had been observed in Experiment 987.

There was an indication in Experiments 1033 and 1051 that the response to styramate was associated with sex. In Experiment 1033 backfat was decreased and percent lean cuts increased in gilts when styramate was added to the ration. The opposite effect was observed in the case of the barrows. In Experiment 1051 the gilts on the three higher levels of styramate had less backfat than the controls and yielded about the same percent lean cuts as those on the control ration. However, the barrows on all levels of styramate had more backfat and a considerably lower percent lean cuts than the barrows on the control ration.

The plasma unesterified fatty acid levels measured in Experiment 1050 suggested that styramate has an effect on UFA mobilization different from that of growth hormone as reported by Raben and Hollenberg (1958) and Engel et al. (1959). In

Experiment 1050 plasma UFA levels were elevated in the controls as well as the growth hormone group, whereas, there was essentially no change in the UFA levels of the pigs injected with styramate. However, since Gordon and Cherkes (1956) have shown that epinephrine administration results in a considerable elevation in the circulating UFA levels, these UFA changes may have been associated with differences in the secretion rates of epinephrine between treatments.

SUMMARY

Arsenical Studies

Four experiments involving 292 pigs were conducted to study the effect of 3-nitro-4-hydroxyphenylarsonic acid (3-N-4-HPAA) on carcass leanness. In each of these experiments at least one of the measurements used for evaluating carcass leanness (live probe, carcass backfat or percent lean cuts) suggested that 3-N-4-HPAA increased carcass leanness.

There was no significant treatment effect on percent lean cuts in the three experiments in which the lean cuts were weighed. However, in one experiment in which 47 pigs from the control ration and 54 pigs from the 3-N-4-HPAA ration were slaughtered, the pigs fed 3-N-4-HPAA yielded a slightly higher percent of lean cuts than the control pigs.

In one experiment there was a significant 3-N-4-HPAA x protein level interaction on carcass backfat as the addition of the arsenical to the "high" protein ration resulted in a decrease in carcass backfat. Dressing percent was significantly higher when 3-N-4-HPAA was added to the ration in this trial. In this experiment the feeding of the "high" protein ration resulted in a highly significant improvement in carcass leanness in all four measurements used - live probe at both 130 and 200 pounds body weight, carcass backfat measured at the packing plant and percent lean cuts.

Cod Liver Oil Studies

In two experiments involving 144 pigs the feeding of cod liver oil failed to increase carcass leanness. There was very little difference between treatments with respect to rate of gain; however, feed efficiency was improved when cod liver oil was included in the ration. In one experiment in which cod liver oil was fractionated into the saponifiable and non-saponifiable fractions, there was an increase in percent lean cuts when the saponifiable fraction was fed.

Styramate Studies

Three experiments involving 224 pigs were conducted to evaluate the effect of styramate, a muscle relaxant, on carcass leanness. In one experiment the addition of styramate to the ration resulted in significantly faster gains and a significant improvement in feed efficiency. In this experiment live probes taken at 110 and 200 pounds body weight indicated the styramate-fed pigs were leaner. In this experiment the pigs fed styramate yielded a significantly higher percent of lean cuts than the control pigs. In two subsequent experiments styramate failed to affect carcass leanness significantly. There was an indication in the two latter experiments that the response to styramate was associated with sex. The gilts fed styramate were slightly leaner than the controls,

whereas, the barrows fed styramate were fatter than the controls as measured by carcass backfat and percent lean cuts.

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APPENDIX

Table 1. Composition of the basal rations[a]

	Experiment				
	811	811	811	877	877
Weight range (lb.):	30-75	75-140	140-200	25-125	125-200
Ground yellow corn (9.5 percent protein)	72.05	80.40	87.80	78.55	88.60
Solvent soybean oil meal (49.1 percent protein)	23.00	14.70	7.50	17.00	7.00
Calcium carbonate (39 percent calcium)	0.75	0.60	0.80	0.55	0.50
Dicalcium phosphate (23 percent calcium) (17 percent phosphorus)	1.60	1.70	1.30	1.30	1.30
Iodized salt	0.50	0.50	0.50	0.50	0.50
Trace mineral premix (35C-41)[b]	0.10	0.10	0.10	0.10	0.10
Vitamin premix[c]	2.00	2.00	2.00	2.00	2.00
Total (lb.)	100.00	100.00	100.00	100.00	100.00

[a]Calculated analyses of basal rations are presented in Table 4.

[b]Composition of trace mineral mix (35C-41) is presented in Table 10.

[c]Amounts of vitamins added are presented in Table 7.

Table 2. Composition of the basal rations[a]

Ingredient	Experiment 888					
Weight range (lb.):	30-50		50-125		125-200	
Percent protein:	20	14	18	12	16	10
Ground yellow corn (8.3 percent protein)	66.80	81.00	71.75	86.00	76.50	90.80
Solvent soybean oil meal (50 percent protein)	28.60	14.20	23.80	9.40	19.00	4.50
Calcium carbonate (38 percent calcium)	0.85	0.75	0.90	0.75	0.85	0.75
Dicalcium phosphate (26 percent calcium) (18 percent phosphorus)	1.15	1.45	0.95	1.25	1.05	1.35
Iodized salt	0.50	0.50	0.50	0.50	0.50	0.50
Trace mineral mix (35C-41)[b]	0.10	0.10	0.10	0.10	0.10	0.10
Vitamin premix[c]	2.00	2.00	2.00	2.00	2.00	2.00
Total (lb.)	100.00	100.00	100.00	100.00	100.00	100.00

[a]Calculated analyses of basal rations are presented in Table 5.

[b]Composition of trace mineral mix (35C-41) is presented in Table 10.

[c]Amounts of vitamins added are presented in Table 8.

Table 3. Composition of the basal rations[a]

	Experiment				
			Period		
			Start-ing	Grow-ing	Finish-ing
					975
				975	987
				987	1033
				1033	1050
	941	962	975	1051	1051
Ground yellow corn (8.3 percent protein)	76.20	77.20	56.20	79.15	86.50
Dried whey (70 percent lactose)			15.00		
Corn starch[b]	4.00	3.00			
Solvent soybean oil meal (50 percent protein)	15.00	15.00	22.50	16.10	8.85
Stabilized lard			2.00		
Calcium carbonate (38 percent calcium)	0.75	0.75	0.80	0.80	0.80
Dicalcium phosphate (26 percent calcium) (18 percent phosphorus)	1.45	1.45	0.85	1.35	1.25
Iodized salt	0.50	0.50	0.50	0.50	0.50
Trace mineral mix (35C-41)[c]	0.10	0.10	0.10	0.10	0.10
Vitamin premix[d]	2.00	2.00	2.00	2.00	2.00
Total (lb.)	100.00	100.00	100.00	100.00	100.00

[a]Calculated analyses of basal rations are presented in Table 6.

[b]Cod liver oil was substituted at the expense of corn starch.

[c]Composition of trace mineral mix (35C-41) is presented in Table 10.

[d]Amounts of vitamins added are presented in Table 9.

Table 4. Calculated analyses of basal rations

Item	Weight range (lb.):	Experiment 811 30-75	811 75-140	811 140-200	877 25-125	877 125-200
Protein	percent	18.31	15.04	12.00	15.99	12.02
Fat	percent	2.93	3.20	3.45	3.13	3.38
Fiber	percent	2.54	2.50	2.47	2.52	2.42
Calcium	percent	0.76	0.70	0.66	0.70	0.66
Phosphorus	percent	0.62	0.60	0.51	0.54	0.51
Vitamin A	I.U./lb.	2500	1504	1578	2005	1500
Vitamin D_2	I.U./lb.	500	300	200	400	200
Riboflavin	mg./lb.	4	1.5	1.4	2.5	1.4
Pantothenic acid	mg./lb.	8	5	4	6	4
Niacin	mg./lb.	25	15	10	20	10
Choline	mg./lb.	467	356	278	382	271
Vitamin B_{12}	mcg./lb.	20	5	4	10	4

Table 5. Calculated analyses of basal rations

Item	Weight range (lb.):	Experiment 888					
		30-50		50-125		125-200	
	Protein level:	High	Low	High	Low	High	Low
Protein	percent	20.00	14.00	18.02	12.00	16.02	9.95
Fat	percent	2.75	3.87	2.91	3.81	3.08	3.55
Fiber	percent	2.58	2.51	2.55	2.48	2.53	2.46
Productive energy[a]	Cal./lb.	951	1043	999	1069	1022	1092
Calcium	percent	0.70	0.70	0.65	0.65	0.65	0.65
Phosphorus	percent	0.55	0.55	0.50	0.50	0.50	0.50
Vitamin A	I.U./lb.	2000	2000	738	880	1085	1230
Vitamin D_2	I.U./lb.	400	400	300	300	300	300
Riboflavin	mg./lb.	2.5	2.5	1.5	1.5	1.5	1.5
Pantothenic acid	mg./lb.	6	6	5	5	5	5
Niacin	mg./lb.	20	20	15	15	15	15
Choline	mg./lb.	509	351	457	298	404	245
Vitamin B_{12}	mcg./lb.	10	10	5	5	5	5

[a]Chick productive Calories.

Table 6. Calculated analyses of basal rations

Item		Experiment		Period		
				Start-ing	Grow-ing	Finish-ing
						975
					975	987
					987	1033
					1033	1050
		941	962	975	1051	1051
Protein	percent	13.98	14.06	18.04	15.02	12.02
Fat	percent	3.04	3.08	4.39	3.16	3.40
Fiber	percent	2.40	2.43	2.13	2.50	2.48
Calcium	percent	0.70	0.70	0.70	0.70	0.66
Phosphorus	percent	0.55	0.55	0.55	0.55	0.50
Vitamin A	I.U./lb.	2000	2000	3580	2500	1000
Vitamin D_2	I.U./lb.	300	300	500	400	300
Riboflavin	mg./lb.	2.5	2.5	4	2.5	2
Pantothenic acid	mg./lb.	6	6	8	6	5
Niacin	mg./lb.	20	20	25	20	15
Choline	mg./lb.	400	400	544	371	292
Vitamin B_{12}	mcg./lb.	10	10	20	10	5
Alpha-tocopherol acetate	mg./lb.	10	10			

Table 7. Amounts of vitamins added per pound of complete ration

	Experiment				
	811	811	811	877	877
Weight range (lb.):	30-75	75-140	140-200	95-125	125-200
Vitamin A, I.U.	1780	700	700	1200	614
Vitamin D_2, I.U.	500	300	200	400	200
Riboflavin, mg.	3.36	0.91	0.86	1.91	.86
Pantothenic acid, mg.	4.90	2.14	1.39	3.10	1.41
Niacin, mg.	16.34	6.19	1.22	11.14	1.20
Vitamin B_{12}, mcg.	20	5	4	10	4

Table 8. Amounts of vitamins added per pound of complete ration

	Experiment 888					
Weight range (lb.):	30-50		50-125		125-200	
Protein level:	High	Low	High	Low	High	Low
Vitamin A, I.U.	1313	1169	300	300	300	300
Vitamin D_2, I.U.	400	400	300	300	300	300
Riboflavin, mg.	1.82	1.91	.85	.95	.88	.99
Pantothenic acid, mg.	2.63	3.16	1.80	2.32	1.98	2.50
Niacin, mg.	10.55	10.51	5.51	5.48	5.51	5.48
Vitamin B_{12}, mcg.	10	10	5	5	5	5

Table 9. Amounts of vitamins and butylated hydroxytoluene added per pound of complete ration

Ingredient	Period			
	Starting	Growing	Finishing	
			975	
		975	987	
		987	1033	
	941	1033	1050	
	962	975	1051	1051
Vitamin A, I.U.	1220	3000	1690	116
Vitamin D_2, I.U.	300	500	400	300
Riboflavin, mg.	1.93	1.64	1.91	1.45
Pantothenic acid, mg.	3.23	2.37	3.25	2.53
Niacin, mg.	10.93	16.31	10.37	5.32
Choline	49			
Vitamin B_{12}, mcg.	10	20	10	5
Alpha-tocopherol acetate, mg.	10			
B.H.T., mg.	57	57	57	57

Table 10. Composition of trace mineral mix (35C-41)[a]

Element	Percent in premix	Parts per million added to ration
Iron	7.0	70.4
Copper	0.475	4.8
Cobalt	0.166	1.7
Manganese	5.68	56.8
Zinc	8.10	81.0
Potassium	0.750	7.5
Calcium	5.28	

[a]Added at level of 0.10 percent of ration.

Table 11. Experiment 811 - Summary of average daily gain and feed required per pound of gain

Rep.	Level of 3-N-4-HPAA (%)			
	0	0.0025	0.005	0.01
		Average daily gain (lb.)		
1	1.67	1.56	1.83	1.73
2	1.74	1.91	1.75	1.81
3	1.57	1.66	1.46	1.54
4	1.69	1.90	1.71	1.81
5	1.80	1.83	1.80	1.90
6	1.82	1.97	1.72	1.46
7	1.83	1.61	1.62	1.67
8	1.45	1.39	1.25	1.49
Av.	1.68	1.71	1.62	1.66
		Feed/gain (lb.)		
1	3.42	3.73	3.29	3.48
2	3.26	3.05	2.94	3.05
3	3.31	3.27	3.61	3.09
4	3.18	3.25	3.46	3.20
5	3.04	3.09	3.20	3.03
6	3.47	3.11	3.39	3.77
7	3.38	3.78	3.45	3.45
8	3.35	3.27	3.49	3.47
Av.	3.30	3.32	3.35	3.32

Table 12. Experiment 811 - Summary of live probes

Rep.	Level of 3-N-4-HPAA(%) 0	0.0025	0.005	0.01
	Live probe at 115 pounds body weight (in.)			
1	1.20	1.10	1.27	1.17
2	1.33	1.30	1.07	1.03
3	1.53	0.97	1.17	0.87
4	1.03	0.97	0.83	0.87
5	1.13	1.03	1.03	1.13
6	0.90	0.93	0.87	0.90
7	0.97	0.93	0.90	1.07
8	1.33	1.13	1.13	1.40
Av.	1.18	1.05	1.03	1.05
	Live probe at 200 pounds body weight (in.)			
1	1.63	1.73	2.10	2.07
2	2.23	1.90	1.63	1.83
3	1.90	1.50	1.93	1.50
4	1.60	1.67	1.40	1.30
5	1.60	1.43	1.57	1.90
6	1.60	1.53	1.47	1.40
7	1.57	1.37	1.40	1.53
8	2.03	1.57	1.77	1.87
Av.	1.77	1.59	1.66	1.68

Table 13. Experiment 811 - Analysis of variance plan and observed mean squares for live probe[a]

Source of variation	d.f.	Mean squares 115 lb.	200 lb.
Replications	7	0.6292[b]	1.1470[c]
Treatments	3	0.3320	0.4104
Linear regression	1	0.5406	0.1690
Quadratic regression	1	0.4278	0.7200
Cubic regression	1	0.0276	0.3422
Basal vs. 3-N-4-HPAA	1	0.9801[c]	0.9204
Error	21	0.1482	0.3252
Total	31	0.2746	0.5190

[a]Individual pig considered the experimental unit, data analyzed on the per pig basis.

[b]Statistical significance at P = 0.01 or less.

[c]Statistical significance at P = 0.05 or less.

Table 14. Experiment 877 - Summary of average daily gain, feed required per pound of gain and carcass measurements

Rep.	Additions to basal ration			
	None	3-N-4-HPAA	$CuSO_4$	$CuSO_4$ 3-N-4-HPAA
		Average daily gain (lb.)		
1	1.50	1.59	1.60	1.66
2	1.43	1.45	1.59	1.64
3	1.46	1.43	1.55	1.46
Av.	1.46	1.49	1.58	1.59
		Feed/gain (lb.)		
1	3.70	3.31	3.31	3.33
2	3.32	3.48	3.19	3.03
3	3.35	3.19	3.24	3.22
Av.	3.46	3.33	3.25	3.19
		Live probe at 140 pounds body weight (in.)		
1	1.02	0.89	0.94	1.08
2	1.06	1.06	1.22	1.07
3	1.36	1.24	1.36	1.40
Av.	1.15	1.06	1.17	1.18
		Live probe at 200 pounds body weight (in.)		
1	1.76	1.48	1.59	1.56
2	1.63	1.64	1.74	1.60
3	1.81	1.76	1.68	1.77
Av.	1.73	1.63	1.67	1.64
		Carcass backfat (in.)		
1	1.65	1.48	1.59	1.71
2	1.60	1.76	1.80	1.60
3	1.71	1.80	1.77	1.78
Av.	1.65	1.68	1.72	1.70

Table 14. (Continued)

Rep.	Additions to basal ration: None	3-N-4-HPAA	$CuSO_4$	$CuSO_4$ 3-N-4-HPAA
		Percent lean cuts		
1	48.75	50.32	50.42	47.48
2	49.25	48.84	47.70	48.60
3	48.44	47.84	48.22	48.09
Av.	48.81	49.00	48.78	48.06
		Dressing percent		
1	69.86	69.95	71.42	71.49
2	69.53	69.51	70.05	70.84
3	69.90	69.33	69.52	70.49
Av.	69.76	69.60	70.33	70.94

Table 15. Experiment 877 - Analysis of variance plan and observed mean squares for live probe at 200 pounds and lean cuts

Source of variation	d.f.	Mean squares: Live probe	Lean cuts
Replications	2	1.3610	1.2117
Treatments	3	0.3820	0.5175
3-N-4-HPAA	1	0.7626	0.2160
$CuSO_4$	1	0.1035	0.7154
3-N-4-HPAA x $CuSO_4$	1	0.2800	0.6211
Error	6	0.3708	0.9704
Total	11	0.5539	0.8908

Table 16. Experiment 888 - Summary of average daily gain, feed required per pound of gain and carcass measurements

Rep.	Treatments			
	Low protein		High protein	
	Basal	3-N-4-HPAA	Basal	3-N-4-HPAA
	Average daily gain (lb.)			
1	1.47	1.55	1.46	1.49
2	1.41	1.47	1.56	1.58
3	1.58	1.58	1.49	1.40
4	1.38	1.43	1.46	1.49
5	1.46	1.49	1.45	1.51
Av.	1.46	1.50	1.48	1.49
	Feed/gain (lb.)			
1	3.67	3.53	3.66	3.50
2	3.58	3.66	3.31	3.37
3	3.45	4.12	3.48	3.94
4	3.62	3.69	3.53	3.64
5	3.56	3.38	3.52	3.50
Av.	3.58	3.68	3.50	3.59
	Live probe at 130 pounds body weight (in.)			
1	1.13	1.11	1.04	1.02
2	1.29	1.22	1.08	1.04
3	1.21	1.19	1.06	1.13
4	1.13	1.24	1.07	1.02
5	1.28	1.25	1.11	0.96
Av.	1.21	1.20	1.07	1.03
	Live probe at 200 pounds body weight (in.)			
1	1.66	1.81	1.51	1.63
2	1.68	1.69	1.64	1.55
3	1.70	1.78	1.62	1.60
4	1.57	1.74	1.65	1.62
5	1.78	1.74	1.60	1.58
Av.	1.68	1.75	1.60	1.60

Table 16. (Continued)

Rep.	Treatments: Low protein, Basal	Low protein, 3-N-4-HPAA	High protein, Basal	High protein, 3-N-4-HPAA
		Carcass backfat (in.)		
1	1.73	1.84	1.56	1.57
2	1.70	1.65	1.52	1.45
3	1.74	1.73	1.57	1.52
4	1.53	1.76	1.61	1.42
5	1.72	1.66	1.62	1.46
Av.	1.68	1.73	1.58	1.48
		Carcass length (in.)		
1	28.6	28.9	28.4	29.8
2	29.8	29.3	29.6	30.2
3	29.0	29.5	29.6	29.4
4	29.4	29.0	28.5	29.6
5	29.6	29.3	29.4	29.6
Av.	29.3	29.2	29.3	29.7
		Percent lean cuts		
1	47.72	46.71	50.12	49.41
2	47.28	47.49	50.00	49.35
3	46.78	47.31	49.49	49.68
4	48.91	47.50	50.52	50.62
5	47.08	46.83	49.33	49.59
Av.	47.55	47.17	49.89	49.73
		Dressing percent		
1	70.92	71.06	69.32	70.92
2	69.80	70.19	69.12	69.96
3	70.19	71.42	69.70	69.69
4	69.73	70.92	69.92	70.46
5	69.19	69.32	68.94	69.65
Av.	69.97	70.58	69.40	70.14

Table 17. Experiment 888 - Analysis of variance plan and observed mean squares for average daily gain, feed required per pound of gain and carcass measurements

Source of variation	d.f.	Average daily gain	Feed/gain	Live probe 130 lb.	Live probe 200 lb.	Carcass backfat	Lean cuts	Dressing percent
Replications	4	0.0033	0.0477[a]	0.0202	0.0044	0.0272	0.8715	1.0142[a]
Treatments	3	0.0018	0.0260	0.1587	0.1050	0.2396	10.1502	1.1943[a]
Protein	1	0.0002	0.0328[b]	0.4606[a]	0.2565[a]	0.6160[a]	30.0125[a]	1.2802[b]
3-N-4-HPAA	1	0.0036	0.0024	0.0104	0.0221	0.0130	0.3754	2.2849[a]
Protein x 3-N-4-HPAA	1	0.0015	0.0429[a]	0.0052	0.0365	0.0898[b]	0.0627	0.0180
Error	12	0.0041	0.0036	0.0116	0.0141	0.0165	0.1528	0.1854
Total	19	0.0036	0.0350	0.0366	0.0264	0.0540	1.8826	0.5192

[a]Statistical significance at P = 0.01 or less.

[b]Statistical significance at P = 0.05 or less.

Table 18. Experiment 975 - Summary of average daily gain, feed required per pound of gain and carcass measurements

Rep.	Treatment	No. of pigs slaughtered	Average daily gain (lb.)	Feed/gain (lb.)	Live probe (in.)	Carcass backfat (in.)	Carcass length (in.)	Percent lean cuts	Dressing percent
1	Basal	9	1.57	3.10	1.33	1.67	29.3	48.13	70.80
	3-N-4-HPAA	9	1.51	3.02	1.38	1.68	28.8	48.30	68.88
2	Basal	7	1.32	3.78	1.47	1.79	27.8	48.55	71.11
	3-N-4-HPAA	9	1.45	3.06	1.31	1.64	29.1	49.29	70.20
3	Basal	7	1.34	3.09	1.29	1.64	29.2	49.34	69.77
	3-N-4-HPAA	9	1.52	2.86	1.19	1.52	30.7	49.49	69.74
4	Basal	9	1.29	3.28	1.46	1.71	28.7	48.82	69.69
	3-N-4-HPAA	9	1.41	3.14	1.32	1.63	29.3	48.76	69.36
5	Basal	9	1.50	3.07	1.29	1.65	29.7	48.49	70.13
	3-N-4-HPAA	9	1.43	3.24	1.48	1.77	28.6	48.46	71.05
6	Basal	6	1.21	3.27	1.54	1.90	28.8	47.99	71.33
	3-N-4-HPAA	9	1.34	3.17	1.43	1.74	29.2	49.12	71.61
Av.	Basal	47	1.37	3.26	1.40	1.73	28.9	48.55	70.47
	3-N-4-HPAA	54	1.44	3.08	1.35	1.66	29.3	48.90	70.14

Table 19. Experiment 975 - Analysis of variance plan and observed mean squares for average daily gain, feed required per pound of gain and carcass measurements

Source of variation	d.f.	Mean squares				
		Average daily gain	Feed/gain	Live probe	Carcass backfat	Lean cuts
Replications	5	0.1469	0.0203	0.1122	0.1154	3.1282
Treatments	1	0.1387	0.0397	0.0565	0.1077	3.3707
Error	5	0.0533	0.0134	0.0832	0.0533	1.0260
Total	11	0.1036	0.0190	0.0940	0.0865	2.1947

Table 20. Experiment 941 - Summary of average daily gains, feed required per pound of gain and carcass measurements

Rep.	Control	Treatment: 2% cod liver oil	4% cod liver oil	Saponifiable fraction	Non-saponifiable fraction
			Average daily gain (lb.)		
1	1.51	1.52	1.52	1.50	1.65
2	1.32	1.50	1.51	1.30	1.42
Av.	1.42	1.51	1.52	1.40	1.54
			Feed/gain (lb.)		
1	4.20	4.15	3.97	4.16	4.32
2	4.39	4.06	3.96	5.40	4.29
Av.	4.30	4.10	3.96	4.78	4.30
			Live probe at 200 pounds (in.)		
1	1.42	1.42	1.40	1.38	1.47
2	1.32	1.35	1.48	1.32	1.38
Av.	1.37	1.38	1.44	1.35	1.42
			Carcass backfat (in.)		
1	1.54	1.51	1.53	1.46	1.52
2	1.50	1.58	1.69	1.53	1.50
Av.	1.52	1.54	1.61	1.50	1.51
			Carcass length (in.)		
1	29.1	29.3	28.4	29.0	29.0
2	29.4	29.4	29.1	29.1	28.8
Av.	29.2	29.4	28.8	29.0	28.9

Table 20. (Continued)

Rep.	Control	Treatment: 2% cod liver oil	4% cod liver oil	Saponifiable fraction	Non-saponifiable fraction
			Percent lean cuts		
1	50.24	51.21	50.49	51.06	50.08
2	51.33	50.90	49.99	52.23	52.03
Av.	50.78	51.06	50.24	51.64	51.06
			Dressing percent		
1	71.12	70.59	70.32	70.37	69.39
2	69.12	69.84	70.63	68.64	69.99
Av.	70.12	70.22	70.48	69.50	69.69

Table 21. Experiment 941 - Analysis of variance plan and observed mean squares for average daily gain, feed required per pound of gain and carcass measurements

Source of variation	d.f.	Mean squares				
		Average daily gain	Feed/gain	Live probe	Carcass backfat	Lean cuts
Replications	1	0.0423	0.1690	0.0057	0.0057	1.1560
Treatments	4	0.0078	0.1901	0.0028	0.0041	0.5181
Error	4	0.0065	0.1556	0.0027	0.0032	0.5492
Total	9	0.0111	0.1724	0.0031	0.0039	0.6028

Table 22. Experiment 962 - Summary of average daily gains, feed required per pound of gain and carcass measurements

Rep.	Level of cod liver oil (%) 0	1	2	3
		Average daily gain (lb.)		
1	1.78	1.82	1.88	1.86
2	1.84	1.67	1.88	1.86
3	1.78	1.95	2.02	1.88
Av.	1.80	1.81	1.93	1.87
		Feed/gain (lb.)		
1	3.95	3.52	3.70	3.61
2	3.96	3.93	3.51	3.65
3	3.99	3.61	3.64	3.58
Av.	3.97	3.69	3.62	3.61
		Live probe (in.)		
1	1.53	1.46	1.58	1.61
2	1.49	1.59	1.40	1.54
3	1.50	1.44	1.54	1.48
Av.	1.51	1.50	1.51	1.54
		Carcass backfat (in.)		
1	1.52	1.56	1.63	
2	1.65	1.64	1.52	
3	1.59	1.59	1.68	
Av.	1.59	1.60	1.61	
		Carcass length (in.)		
1	29.9	29.4	29.2	
2	29.3	29.1	29.4	
3	29.4	29.7	29.0	
Av.	29.5	29.4	29.2	

Table 22. (Continued)

Rep.	Level of cod liver oil (%) 0	1	2	3
		Percent lean cuts		
1	50.24	51.62	49.80	
2	51.06	50.27	51.07	
3	51.99	50.53	50.24	
Av.	51.10	50.81	50.37	
		Dressing percent		
1	67.31	67.25	67.14	
2	69.12	68.66	67.55	
3	68.14	67.00	67.98	
Av.	68.19	67.64	67.56	

Table 23. Experiment 962 - Analysis of variance plan and observed mean squares for average daily gain, feed required per pound of gain and live probe

Source of variation	d.f.	Mean squares: Average daily gain	Feed/gain	Live probe
Replications	2	0.0645	0.0053	0.0032
Treatments	3	0.0592	0.0840[a]	0.0013
Linear regression	1	0.0865	0.1915[a]	0.0022
Quadratic regression	1	0.0312	0.0574	0.0016
Cubic regression	1	0.0598	0.0031	0.0000
Error	6	0.0559	0.0174	0.0057
Total	11	0.0584	0.0334	0.0040

Table 24. Experiment 962 - Analysis of variance plan and observed mean squares for carcass backfat and lean cuts

Source of variation	d.f.	Mean squares	
		Carcass backfat	Lean cuts
Replications	2	0.0020	0.1048
Treatments	2	0.0004	0.4014
Linear regression	1	0.0008	0.7921
Quadratic regression	1	0.0000	0.0108
Error	4	0.0053	0.7954
Total	8	0.0032	0.5242

Table 25. Experiment 987 - Summary of average daily gain, feed required per pound of gain and carcass measurements

Rep.	Styramate (mg./lb.) 0	50	100	200	400	800
			Average daily gain (lb.)			
1	1.43	1.54	1.55	1.49	1.62	1.64
2	1.46	1.49	1.48	1.42	1.44	1.62
Av.	1.44	1.52	1.52	1.46	1.53	1.63
			Feed/gain (lb.)			
1	3.17	3.15	2.97	3.15	3.04	2.98
2	3.22	3.02	3.07	3.17	3.12	2.93
Av.	3.20	3.08	3.02	3.16	3.08	2.96
			Live probe at 110 pounds body weight (in.)			
1	0.86	0.83	0.70	0.78	0.86	0.69
2	0.87	0.79	0.78	0.83	0.80	0.77
Av.	0.86	0.81	0.74	0.80	0.83	0.73
			Live probe at 200 pounds body weight (in.)			
1	1.38	1.34	1.38	1.36	1.40	1.32
2	1.43	1.40	1.42	1.40	1.41	1.30
Av.	1.40	1.37	1.40	1.38	1.40	1.31
			Carcass backfat (in.)			
1	1.74	1.62	1.67	1.63	1.66	1.62
2	1.70	1.64	1.70	1.61	1.63	1.67
Av.	1.72	1.63	1.68	1.62	1.64	1.64
			Carcass length (in.)			
1	29.0	29.6	29.1	29.4	28.8	29.6
2	28.8	29.1	28.7	29.4	29.0	29.0
Av.	28.9	29.4	28.9	29.4	28.9	29.3

Table 25. (Continued)

Rep.	Styramate (mg./lb.) 0	50	100	200	400	800
			Loin eye area (sq. in.)			
1	3.58	3.57	3.87	3.51	3.55	3.61
2	3.81	3.54	3.75	3.77	3.84	3.67
Av.	3.70	3.56	3.81	3.64	3.70	3.64
			Percent lean cuts			
1	50.13	50.56	50.75	50.27	50.38	51.08
2	50.16	50.86	51.23	50.63	50.79	51.28
Av.	50.14	50.71	50.99	50.45	50.58	51.18
			Dressing percent			
1	68.00	68.40	69.86	69.52	67.85	68.28
2	68.49	68.39	68.62	68.62	68.82	68.57
Av.	68.24	68.40	69.24	69.07	68.34	68.42

Table 26. Experiment 987 - Analysis of variance plan and observed mean squares for average daily gain, feed required per pound of gain and carcass measurements

Source of variation	d.f.	Average daily gain	Mean squares					
			Feed/gain	Live probe 110 lb.	Live probe 200 lb.	Carcass backfat	Loin eye area	Lean cuts
Replications	1	0.0567	0.0004	0.0100	0.0142	0.0000	0.0397	1.5606[a]
Treatments	5	0.0504	0.0155	0.0311	0.0177[b]	0.0172	0.0064	1.6846[a]
Linear regression	1	0.1848[b]	0.0388[b]	0.0480	0.0538[a]	0.0112	0.0011	3.3717[a]
Quadratic regression	1	0.0088	0.0015	0.0036	0.0187[b]	0.0175	0.0008	0.1507
Remainder	3	0.0195	0.0125	0.0347	0.0053	0.0190	0.0100	1.6336[a]
Error	5	0.0144	0.0038	0.0109	0.0025	0.0036	0.0023	0.0804
Total	11	0.0346	0.0088	0.0200	0.0105	0.0094	0.0167	0.9442

[a]Statistical significance at P = 0.01 or less.

[b]Statistical significance at P = 0.05 or less.

Table 27. Experiment 1033 - Summary of average daily gain, feed required per pound of gain and carcass measurements

Rep.	Styramate (mg./lb.) 0	400	800	1200
		Average daily gain (lb.)		
1	1.60	1.56	1.58	1.51
2	1.44	1.45	1.44	1.42
3	1.45	1.44	1.31	1.35
Av.	1.50	1.48	1.44	1.43
		Feed/gain (lb.)		
1	3.76	3.81	3.92	3.93
2	3.86	3.94	3.67	3.87
3	3.65	3.61	3.96	3.92
Av.	3.76	3.79	3.85	3.91
		Live probe (in.)		
1	1.36	1.26	1.35	1.24
2	1.40	1.44	1.48	1.41
3	1.43	1.43	1.47	1.44
Av.	1.40	1.38	1.43	1.36
		Carcass backfat (in.)		
1	1.53	1.50	1.62	1.48
2	1.64	1.64	1.65	1.62
3	1.64	1.65	1.72	1.60
Av.	1.60	1.60	1.66	1.57
		Carcass length (in.)		
1	30.4	30.7	30.0	30.5
2	29.7	29.7	29.5	29.6
3	29.4	29.3	29.5	28.8
Av.	29.8	29.9	29.7	29.6

Table 27. (Continued)

Rep.	Styramate (mg./lb.) 0	400	800	1200
		Loin eye area (sq. in.)		
1	3.12	3.34	3.40	3.42
2	3.28	3.19	3.34	3.42
3	3.69	3.46	3.30	3.39
Av.	3.36	3.33	3.35	3.41
		Percent lean cuts		
1	51.34	52.50	51.50	53.37
2	51.05	50.56	50.97	51.23
3	51.25	50.24	49.65	51.92
Av.	51.21	51.10	50.71	52.17
		Dressing percent		
1	67.91	67.95	68.58	66.82
2	68.52	68.46	68.14	68.56
3	68.71	68.56	70.25	68.38
Av.	68.38	68.32	68.99	67.92

Table 28. Experiment 1033 - Analysis of variance plan and observed mean squares for average daily gain, feed required per pound of gain and carcass measurements

Source of variation	d.f.	Mean squares: Average daily gain	Feed/gain	Live probe	Carcass backfat	Loin eye area	Percent lean cuts
Replications	2	0.0333[a]	0.0052	0.1410[a]	0.1000[a]	0.0070	14.1310[b]
Treatments	3	0.0031	0.0134	0.0149	0.0284[b]	0.0152	6.9769
Linear regression	1	0.0091[b]	0.0395	0.0041	0.0069	0.0224	9.2214
Quadratic regression	1	0.0000	0.0005	0.0151	0.0461[b]	0.0162	10.1419
Cubic regression	1	0.0002	0.0002	0.0255	0.0322[b]	0.0070	1.5675
Error	6	0.0014	0.0197	0.0079	0.0046	0.0228	2.5230
Total	11	0.0077	0.0154	0.0340	0.0284	0.0179	5.8482

[a]Statistical significance at P = 0.01 or less.

[b]Statistical significance at P = 0.05 or less.

Table 29. Experiment 1051 - Summary of average daily gain, feed required per pound of gain and carcass measurements

Rep.	Styramate (mg./lb.) 0	100	200	400	800
			Average daily gain (lb.)		
1	1.83	1.93	1.99	1.86	1.87
2	1.82	1.82	1.88	1.84	1.80
3	1.90	1.84	1.90	1.92	1.88
4	1.72	1.82	1.79	1.74	1.68
Av.	1.82	1.85	1.87	1.84	1.81
			Feed/gain (lb.)		
1	3.31	3.42	3.39	3.23	3.22
2	3.49	3.35	3.57	3.29	3.50
3	3.49	3.37	3.38	3.24	3.45
4	3.32	3.34	3.55	3.35	3.62
Av.	3.40	3.37	3.47	3.28	3.45
			Live probe (in.)		
1	1.21	1.43	1.27	1.28	1.31
2	1.36	1.33	1.32	1.38	1.33
3	1.44	1.40	1.29	1.35	1.24
4	1.40	1.53	1.42	1.49	1.48
Av.	1.35	1.42	1.32	1.38	1.34
			Carcass backfat (in.)		
1	1.48	1.66	1.56	1.54	1.61
2	1.61	1.60	1.56	1.56	1.55
3	1.54	1.64	1.53	1.62	1.57
4	1.62	1.74	1.63	1.61	1.75
Av.	1.56	1.66	1.57	1.58	1.62

Table 29. (Continued)

Rep.	Styramate (mg./lb.) 0	100	200	400	800
			Carcass length (in.)		
1	30.8	30.5	30.6	30.4	30.1
2	28.6	29.5	29.2	28.8	29.5
3	29.8	29.5	30.9	30.2	29.7
4	28.8	28.8	28.6	29.2	28.1
Av.	29.5	29.6	29.8	29.6	29.4
			Loin eye area (sq. in.)		
1	3.60	3.16	3.16	3.46	3.30
2	3.43	3.56	3.88	3.71	3.89
3	3.53	3.32	3.30	3.10	3.08
4	3.79	3.62	3.27	3.08	3.19
Av.	3.59	3.42	3.41	3.34	3.36
			Percent lean cuts		
1	51.99	50.04	51.60	52.56	51.24
2	50.64	51.49	50.80	50.87	50.10
3	50.62	49.51	51.77	50.34	50.45
4	51.64	49.73	49.96	49.56	49.45
Av.	51.22	50.19	51.03	50.83	50.31
			Dressing percent		
1	68.21	68.54	68.95	67.55	67.44
2	68.20	67.53	69.00	68.36	69.20
3	67.83	67.64	68.53	67.83	68.25
4	68.90	69.00	68.68	68.61	69.02
Av.	68.28	68.18	68.79	68.09	68.48

Table 30. Experiment 1051 - Analysis of variance plan and observed mean squares for average daily gain, feed required per pound of gain and carcass measurements

Source of variation	d.f.	Mean squares: Average daily gain	Feed/gain	Live probe	Carcass backfat	Loin eye area	Percent lean cuts
Replications	3	0.0760[a]	0.0172	0.1011[a]	0.0445[b]	0.7041	6.9670
Treatments	4	0.0119	0.0232	0.0221	0.0260[b]	0.1516	3.2397
Linear regression	1	0.0076	0.0009	0.0083	0.0044	0.2839	2.9322
Quadratic regression	1	0.0300[b]	0.0226	0.0007	0.0015	0.2574	0.1264
Remainder	2	0.0049	0.0348[b]	0.0398	0.0490[b]	0.0326	9.9003[b]
Error	12	0.0054	0.0089	0.0143	0.0078	0.2198	2.3976
Total	19	0.0179	0.0139	0.0297	0.0174	0.2819	3.2964

[a]Statistical significance at P = 0.01 or less.

[b]Statistical significance at P = 0.05 or less.

Table 31. Experiment 1050 - Summary of plasma unesterified fatty acid levels

Treatment	Pig number	Sex	Unesterified fatty acids (microequivalents/liter) Initial	Final	Increase from initial to final
Control	7311	gilt	244	356	112
	7315	boar	206	375	169
	7318	barrow	113	643	530
	7350	gilt	169	163	-6
	7357	boar	150	256	106
	7359	barrow	150	269	119
		Average	172	344	172
Growth hormone	7310	gilt	94	450	356
	7313	boar	113	312	199
	7316	barrow	206	419	213
	7354	gilt	225	300	75
	7319	boar	187	356	169
	7345	barrow	244	331	87
		Average	178	361	183
Styramate	7312	gilt	300	238	-62
	7317	boar	375	269	-106
	7314	barrow	375	419	44
	7355	gilt	113	269	156
	7350	boar	282	206	-76
	7358	barrow	150	206	56
		Average	266	268	2

Table 32. Experiment 1050 - Analysis of variance plan and observed mean squares for unesterified fatty acids[a]

Source of variation	d.f.	Mean squares
Outcome groups	5	16516
Barrow + gilt vs. boar	1	15960
Gilt vs. boar	1	2408
Outcome group/sex	3	21404
Treatments	2	61740
Styramate vs. G.H. + control	1	123084[b]
Control vs. G.H.	1	398
Error	10	19044
Total	17	23324

[a]Individual pig considered the experimental unit, data analyzed on the per pig basis.

[b]Statistical significance at P = 0.05 or less.

Table 33. Summary of diagnoses for pigs removed from experiments

Experiment number	Pig number	Treatment	Diagnosis
941	9405B	Saponifiable fraction	PPLO-type pneumonia with a large area of suppuration
975	3515S	3-N-4-HPAA	Edema of the lungs, increased fluid in the pericardial, pleural and peritoneal cavities and extensive vegetative endocarditis
975	3713S	3-N-4-HPAA	Umbilical abscess and marked lesions of a PPLO pericarditis and pleuritis and meningitis
987	4070S	Styramate (100 mg./lb.)	Lesions of septicemia salmonellosis
987	3929B	Styramate (100 mg./lb.)	Rectal prolapse
987	4055B	Styramate (50 mg./lb.)	Umbilical rupture
987	3948B	Styramate (400 mg./lb.)	Umbilical rupture
987	4063B	Styramate (200 mg./lb.)	Suppurative perinephritis
987	3922S	Styramate (400 mg./lb.)	Rectal prolapse
987	4062B	Styramate (50 mg./lb.)	Severe extensive suppurative pyelonephritis
1051	7910S	Control	Possibility of toxemia and allergic reactions